FEASIBILITY OF IMPLEMENTING PREFABRICATED U.S. PRODUCTS AND METHODS FOR RESIDENTIAL CONSTRUCTION IN THAILAND

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SUMMARY

Prefabricated construction has been a common construction method in U.S. construction for more than a century. The concept of “build it fast” in the most economical way has not changed since the beginning; however, new technologies have been developed to suit the modern world prefabricated construction. New technologies are not only helping contractors and owners get their buildings faster and more economically but they also help reduce construction waste and produce high energy efficiency buildings which results in a long term benefit to projects.

On the other hand, prefabrication for residential construction has been used in Thailand for only less than two decades, but it has been growing very fast in the past five years. Recently, there have been many new developers, and contractors who have switched from traditional construction to prefabrication to keep up with this new trend in the Thai residential market. Moreover, the new minimum wage policy from the Thai government has hit the construction business very hard. Labor cost has risen by more than 40% in some areas (department of labor, 2013) since 2012. Thai developers see prefabrication as the future and are ready to invest more in this type of construction. (Krunthep Thurakit, 2013)

Currently, there are many construction products from the U.S. that have been used in Thai construction. Thai people are familiar with U.S. products, therefore, U.S. prefabricated products and methods could make a quick transition to Thai prefabricated construction. The finding in this research will benefit both the Thai construction business and U.S. investors from the data of the potential prefabricated U.S. products.

CHAPTER 1

INTRODUCTION

1.1 OVERVIEW

Prefabrication plays an important role in the modern world construction of every building today, it refers to the making of parts in an offsite workshop or factory prior to the installation at the site. “The primary purpose of prefabrication is to produce building components in an efficient work environment with accesses to specialized skills and equipment in order to reduce cost and time expenditures on the site while enhancing quality and consistency” (Anderson and Anderson 2007). It is clear that most new construction will have to use more and more prefabrication. From primary structures to small architectural ornaments, prefabrication has become a major part of building construction.

Although prefabrication is a common method of construction in the U.S. and in many European countries, several countries in Asia are still not familiar with this method. Because those Asian countries have different social and economic systems from the U.S., they tend to use more actual manpower for constructions rather than prefabrication methods. Construction methods that require a lot of physical labor such as masonry, hand paint or cast-in-place concrete are common in Thailand. Because Thailand is an agricultural society, the labor wage for agricultural work in Thailand is much lower than the labor wage for industrial work in the United States. Furthermore, unlike the United States, a lot of countries in Asia including Thailand may have fewer concerns in many important aspects of building construction, such as preciseness, on-site safety, energy saving and waste management during a construction. All these issues can be resolved by prefabrication methods.

Thailand has been trying to transform from an agricultural society to an industrial society. For decades, Thailand has invested a lot of money in education to develop its people in fields that would make its transition to an industrial nation much easier. As a result, labor costs have risen exponentially. Similar to other Asian countries, Thailand is now facing a rising labor cost and a lack of both skilled and un-skilled workers. Many developers and contractors in Thailand also see this problem and respond by using more prefabrication; this attracts many investors from all over the world to invest more in the prefabricated construction business. Currently, there are several residential developers in Thailand that use prefabrication for their projects. In the near future, prefabrication is expected to play a major role in Thai construction, especially, in the residential construction like in many European countries and the United States.

1.2 OBJECTIVE

The intention of this research is to identify prefabricated residential construction products or methods from the U.S. that can be used for developing new or similar products that are compatible with the Thai market. There are a lot of strong potential prefabricated construction products and methods in the U.S. that can be very useful in Thailand. Those can benefit both U.S. investors and Thai construction. Selected products or method will be reviewed and investigated in the following categories: performance, compatibility, availability, price and ability to adapt to the Thai market.

1.3 BACKGROUND

For more than a century, prefabrication has been a solid part of U.S. construction. Prefabrication is known as a fast and affordable type of construction. After World War II, prefabricated construction became popular for in the U.S. The need of homes for the U.S. service men and women who returned to the United States after the war forced builders to build faster. “Eleven million servicemen and –women were returning home to

communities where few unoccupied houses were available. By 1947, more than 5 million families had either doubled up with other families in overcrowded dwellings or were occupying temporary shelters" (Miles, 2007). To meet the high demand, some builders experimented new housing market by creating their own designs and specifications to help build more and faster. Some builders made off-site building components then delivered them to other builders or home buyers rather than building everything at the site. Many "House by Mails" were shipped from the factories, and the result of big benefit has attracted many new investors (Arieff and Burkhart 2002). Since then, many investors have been interested in the prefabrication concept. New factories were built for producing building parts which were then shipped to the site, hence the term "prefabricated construction". Today, many Americans agree that prefabricated construction makes significant impact on both time and budget as shown in figure 1.1. A lot of money, from both the private and public sectors, has been put into research and production to create better prefabricated construction products.

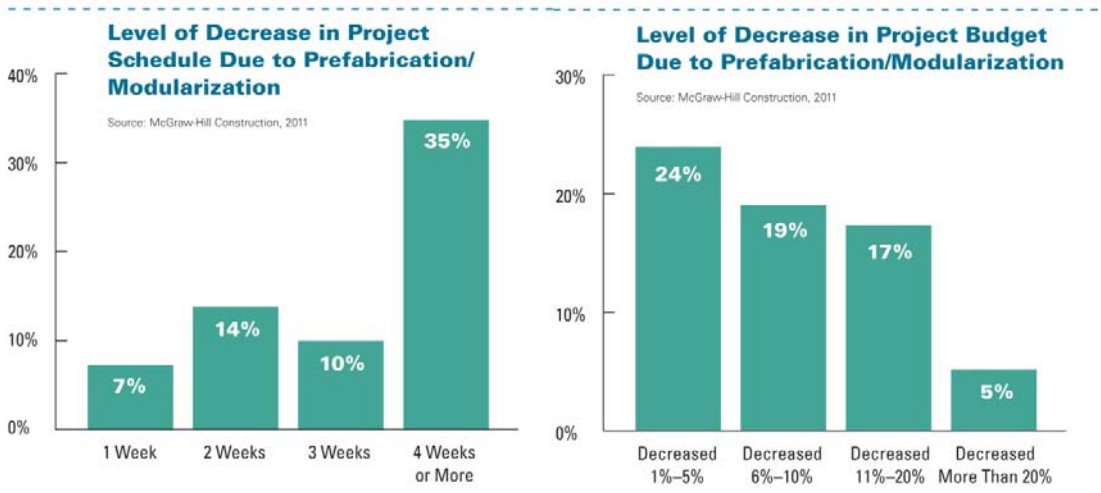


Figure 1.1: Level of Decrease in Project Schedule and in Project Budget (Smart Market Reports: McGraw-Hill Construction, 2011)

Prefabricated construction is popular not only in the United States but also in many other countries. Many developed countries have invested in more research on

prefabricated construction because their fast-growing economies have forced builders to build faster and more economically. Developed countries in Asia such as Japan and South Korea also invest in prefabrication construction research. Just as many developed Western countries, Japan and Korea invent their own construction techniques and conduct their own research, which is suitable for their economies, geographies and populations. Products made in both countries are well distributed locally.

On the other hand, many developing countries in Asia do not have the ability to do their own research or develop their own construction methods or even produce high-tech consumer products, such as electronic appliances. These countries often buy products or use knowledge from developed countries. For example, Thailand, Malaysia, Indonesia and the Philippines use products from the U.S., Japan and many European countries. Many Thais are already familiar with U.S. products, so there are a lot of opportunities for the U.S. companies, especially those in prefabrication construction, to expand their business in Thailand

CHAPTER 2

PREFABRICATION IN THE UNITED STATES

2.1 DEFINITION & SCOPE

Factory-constructed homes, manufactured homes, modular homes, prefabricated homes or prefab homes are common terms used to describe pre-made homes. Today, many American homes are made through prefabricated construction methods. Prefabricated construction helps facilitate the American Dream of home ownership by offering affordable prices to buyers. “The term prefabricated brings to mind a building system in which the essential pieces of structure are sent to the site on which the finished edifice will be constructed partially or completely assembled. Once there, it is necessary only to join and anchor the parts” (Bahamon, 2002). Prefabricated construction does not only reduce construction costs, but it also produces a more stable and fairly remunerated construction industry with improved safety and working conditions, greater investment in research, design creativity, and product development. It also reduces consumption of energy and material and generally increases the availability of better designed and high-quality built environments. (Anderson and Anderson 2007)

Even though in the United States the majority of prefabricated construction is used to build single family homes and residential buildings (multi-family homes such as condominiums or apartments), many of the commercial projects also use the prefabricated construction method. For example, commercial franchise companies like Walgreen, Wal-Mart and McDonalds use prefab methods to build their stores. Because franchise buildings typically have similar specifications and designs, it is very beneficial to choose prefabricated construction methods.

This research will focus mainly on prefabricated construction for single-family residential and multifamily residential buildings in developing Asian countries and more

specifically in Thailand. The purpose of this research is to find out what the most suitable products and methods for the Thai residential construction market.

2.2 HISTORY OF PREFABRICATED CONSTRUCTION IN THE U.S.

The prefabricated building system can be traced as far back as to the seventeenth century when a panelized wood house was shipped from England to Cape Ann in 1642 to provide housing for a fishing fleet (Arieff and Burkhart 2002). In the U.S., apart from the Native American tent known as “Tipi”, which can be referred to as a primitive modular house, the history of American prefabricated houses has been recorded from the California gold rush in 1849. The prefabs in the California gold rush can be best described as “Small building, roughly built, let from twelve to fifteen thousand dollar a year. Tents were popular, and in more sturdy structures, cloth partitions were commonplace. Many lived on ships abandoned in the harbor, even though it cost two dollars to be rowed ashore, lumber at times sold as high as a dollar a square foot and bricks at a dollar a piece. The ready-made building was a logical answer to the emergency. Prefabricated structures were brought to San Francisco from all around the world. Houses were shipped in from as far away as New Zealand, China, and Tasmania.” (Fetters, 2002)

In 1908, the American modern world prefabricated house idea was influenced by Henry Ford’s car factory. Henry Ford’s Model T, the first affordable automobile, successfully demonstrated that mass production could be used to manufacture a high-quality object as large as a car. Industrialization was brought to prefabrication not long after Ford’s Model T went into production, and by the late 1910s, a number of companies had begun to offer high-quality, precut, and prefabricated houses in a great variety of styles (Arieff and Burkhart 2002).

One of the most popular companies and the pioneer in “House by Mail” was Sears, Roebuck & Co. The company sold “House by Mail” to nearly 100,000 clients

during 1908 – 1940. The term “House by Mail” was used to describe the early product of a prefabricated house as included in the book shown in figure 2.1. A “House by Mail” kit includes lumber, nails, shingles, windows, doors, hardware, and house paint. Sears, Roebuck & Co offers a customized “House by Mail” by giving buyers catalogs which they could use to customize their own specifications (Arieff and Burkhart 2002).

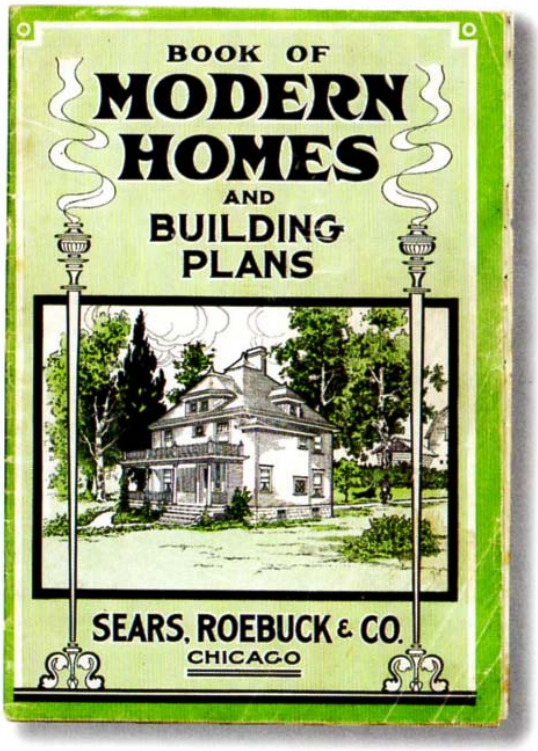


Figure 2.1: House by Mail by Sears, Roebuck & Co. of Chicago

(Arieff and Burkhart 2002)

In the early 1920s, many famous European architects also had the idea of mass-produced housing. The 1920s was a period when many European countries faced with a shortage of houses. Germany, for example, faced with a shortage of 800,000 houses in the mid-‘20s (Fetters, 2002). Le Corbusier, a French architect, developed a number of mass-produced housing schemes during that time. He also wrote an essay “Mass Production Houses” in which he referred to the mass-produced houses as “House-Machine”. Walter Gropius, the founder of Bauhaus, experimented the new mass-

produced housing by using steel to form the fast-built housing structure. Gropius developed “Building Blocks”, a system of standardized flat-roofed housing which he defined as “a new architecture for a new age” (Arieff and Burkhart 2002).

The early American prefabricated construction did not have much impact on European architects’ ideas in terms of construction, but European ideas influenced a lot of American architects in the philosophy of modernist architecture.

In 1933, a number of steel-prototype houses were presented at the Chicago World’s fair. George Fred Keck’s House of Tomorrow (see figure 2.2) and Crystal House were displayed at the fair. The house exhibition was supported by a steel framework and steel-deck floor system. Keck’s Crystal House has an innovative prefabricated structural frame that was erected in just three days, but its bold constructivist aesthetics was too radical for the average home buyer (Arieff and Burkhart 2002).

Figure 2.2: House of Tomorrow by George Fred Keck

(Haus, 2011)

Other systems like the prefabricated panel developed by Howard T. Fisher also facilitated functionality and low cost, but most of the houses utilizing these systems tended to be “boxlike”. Howard T. Fisher is a founder of the General Houses Corporation. The company produced affordable houses ranging in price from $3,000 to

$4,500 in 1932. The houses, which were produced by General Houses Corporation, were made from pressed steel based on standardized parts designed by Fisher (Arieff and Burkhart 2002). As stated by Arieff and Burkhart (2002) “Approximately 18,000 prefabricated homes had been built by the end of 1941. Several federal agencies had been contracted for or had built roughly 1.6 million housing units during the war, of which over 12 percent had been prefabricated”.

In 1947, two years after the end of World War II, Americans faced a shortage of houses because a lot of service men and women who returned home from the war significant raised the demand of housing in the U.S. In 1948, Carl Strandlud, the founder of Luston Corporation, began producing prefabricated all-steel houses (see figure 2.3). “The Lustron house is made almost entirely of metal; the floors are asphalt… and only the built-in shelving and cabinets are wood. The house is being manufactured by Lustron Corporation of Columbus, Ohio will be distributed nationally and is tentatively priced at about $8000” (Fetters, 2002). His company received a $15.5 million loan from the government. Approximately 2,500 Lustron houses were built before the company folded in 1950 (Arieff and Burkhart 2002).

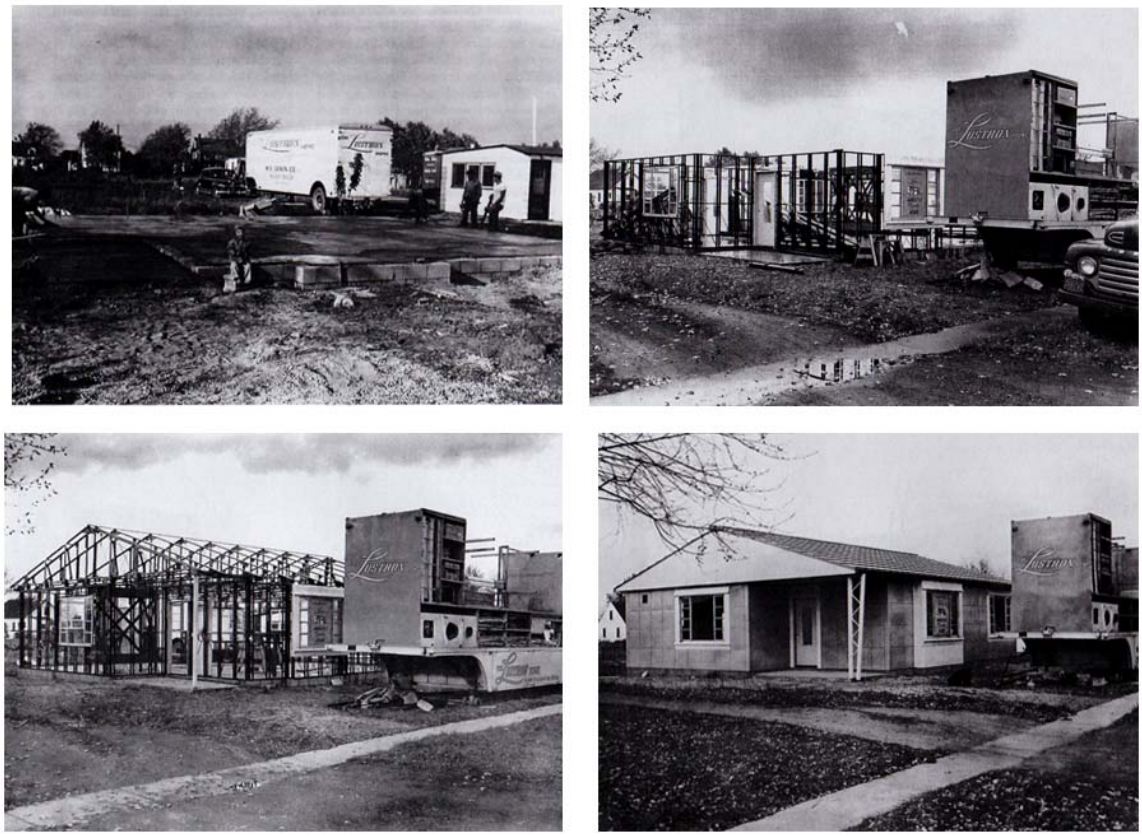


Figure 2.3: Lustron home's construction method

(Fetters, 2002)

During the sixties and seventies, many new issues were raised on the development of prefabricated housing. Rather than focusing only on quick affordable construction, many architects faced a new challenge on designing prefabricated houses. The new challenge came from social issues such as traffic, overpopulation, the energy crisis, and the economy; and the technical issues such as the new system of heating or cooling systems and the concern of low-maintenance houses. In Britain, architect Sir Richard Rogers developed the Zip-Up Enclosures in 1968, a series of inexpensive, low-maintenance shelters that offered a high degree of environmental control and a large range of design choices. Rogers later developed a concept for an Autonomous House that would function as an artificial ecosystem, recycling its own water and waste, heating or

cooling itself using natural energy, and generating its own power (Arieff and Burkhart 2002).

In the U.S., the new housing system took advantage of advances in science and technology from solar panels to space station and applied them to shelter. “Ray Kappe’s Advanced Technology House was commissioned by NASA in the sixties with a primary goal of demonstrating technology transfer to housing” (Arieff and Burkhart, 2002) Since then, there have been a lot of exchanges in technology between construction technology and other products, such as, in construction materials, and building systems.

Prefabrication construction in the late twentieth century was developed on a much bigger scale. New technology provided more options for mass-production. Factories can now produce more complicated building components such as sandwich panels, and precast concrete panels has become a common use in prefabricated construction. Not only has the advanced technology made great changes on the production side, but also the development of digital technology has helped reduce the limitation on the design side. The word, CAD (Computer Aided Design), CAM (Computer Aided Manufacturing) and CNC (Computer Numeric Control) have become common words for architects, contractors and manufacturers. This event is affecting not only prefab technology development, but also the social constructions by which buildings are produced, their contract structure, and the interface of players. Digital fabrication is potentially a method by which the promises of prefabrication – complementary increase in design and production quality – may be realized (Smith, 2010).

Moreover, the new design software for both architects and engineers tries to make the construction drawing more realistic. The BIM (Building Information Modeling) software does not only help architects and engineers to see their project clearer but it also helps on the construction side. The BIM technology allows building designers not only to produce 2D drawings but also create 3D models. These BIM’s 3D models are very useful when the building components are produced from a factory. These BIM’s 3D models

allow the production team from a factory to see any individual building component from a whole building model. “McGraw-Hill Construction (MHC) found that the use of BIM model-driven prefabrication on more than one quarter of their projects is expected to increase from 37% to 73% among practitioners who use BIM for green work. Even those who are currently not using green BIM expect an increase from 22% to 57%” (Smart Market Reports: McGraw-Hill Construction, 2011). The result is that in the near future more and more prefabricated buildings will be built using this method.

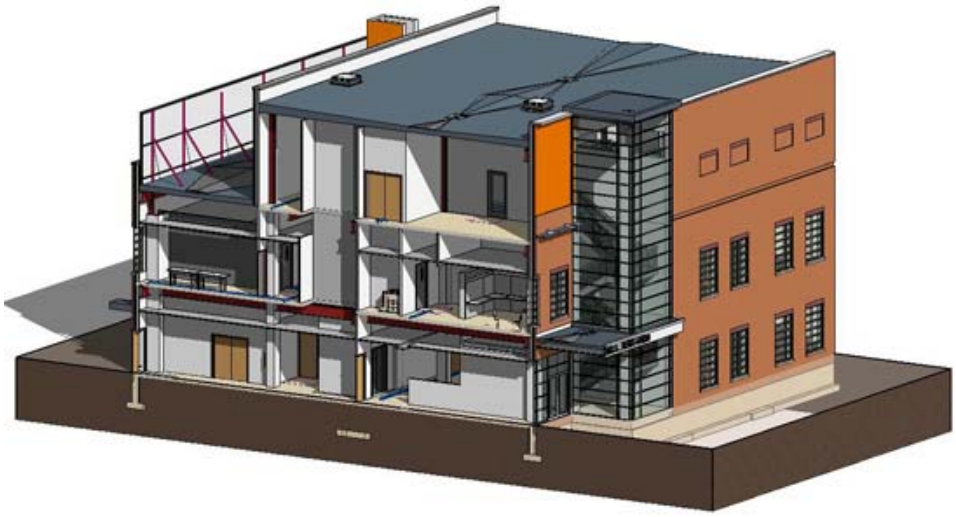


Figure 2.4: BIM model

(AMVIC, 2014)

Today, prefabricated construction has become one of the major components of U.S. construction. As many architects and developers understand that prefabrication construction could be the future in the construction world, more money is being put into research by the government and other private enterprises to develop new technologies for the U.S. prefabricated construction.

2.3 TYPES OF PREFABRICATED CONSTRUCTION IN THE U.S.

Prefabrication, typically, can be categorized in types of materials or degree of prefabrication (see figure 2.5). First, types of material mean any common materials that are used to build the prefabrication components, such as timber, concrete, steel or sometimes the combination of different materials, in the factory. Second, degree of prefabrication is a construction process through which prefabricated elements are assembled on site, from the small piece to the big piece, for example, prefabricated column, panels, tilt-up, and modular methods (Smith, 2010).

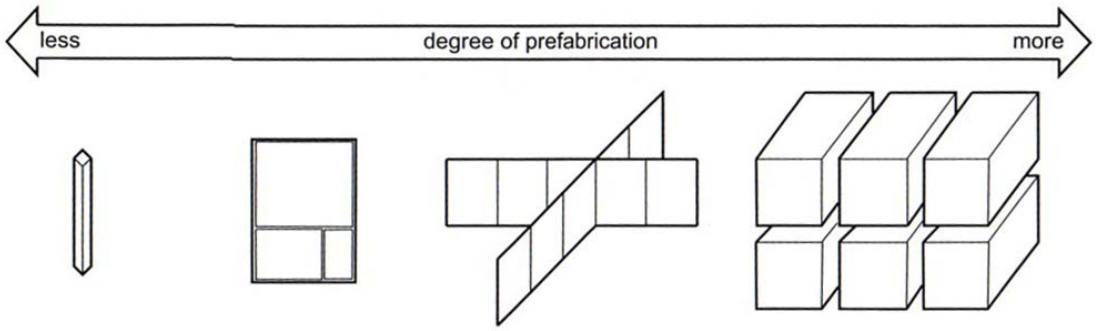


Figure 2.5: Degree of Prefabrication

(Smith, 2010)

2.3.1 Wood framing

Wood is an extremely versatile and environmentally responsible material. It is also one of the few renewable structural materials. Under wise and prudent forestry practices, wood can service building for many years (Smith, 2010). Wood frames or timber frames are the most common materials for any construction. Wood frames today can be manufactured with custom joints, many of which now include metal fasteners (Smith, 2010). Most architects and contractors in the United States are acquainted with wood frames because wood frames have been the primary method of American construction, especially residential, since the nineteenth century (Anderson and Anderson 2007).

The wood panelized building system is also one of the most common types of wood construction in the United States. The method of panelized building system can be referred to as the use of a set of prefabricated wood, 2x4 or 2x6, that is framed together to create a single panel which will be used as a wall or other building components. A panelized system can often be seen as on-site work. Wall sections are typically laid out and assembled flat on the ground, then tipped up into place as units, and finally connected to other sections to form the standing wall of a building (see figure 2.6). This is the simplest way of defining the term prefabrication (Anderson and Anderson 2007).

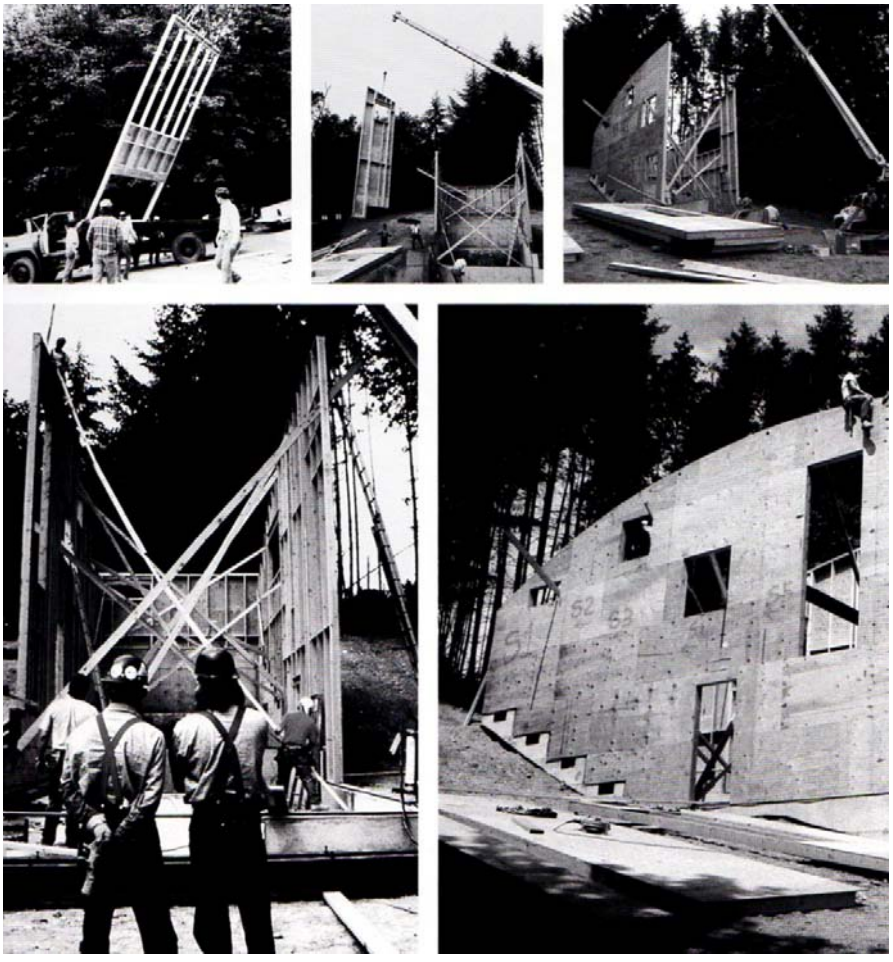


Figure 2.6: Fox Island House's exterior construction

(Anderson and Anderson, 2007)

However, not all units of panelized construction are assembled on-site; many panels are assembled off-site. The off-site panels are assembled in a factory by workers or machines that put together pieces of prefabricated wood to create a wood panel that will eventually be transported to a construction site. The off-site panels not only make the construction process faster, because they also are mass-produced, but they have better quality. Most timber-frame manufactures in the U.S. use advance technology to cut timber. The new generation of CAD/CAM machine helps to produce more precise pieces of wood and better quality wood framing. Furthermore, workers in the timber-frame manufactures do not need to deal with any site constraints, such as slope or limited working area, or unpredictable weather, which results in better quality control.

Although wood framing is easy to use for most construction, architects and contractors need to be very careful when designing or using it. On the design side, wood framing has some design limitations. The simple rectangle wall is ideal for designing wood framing. Having parallel top and bottom plates, for instance, is far easier to automate in a factory than producing walls with slope tops or other irregular dimensions, which may have to be “stick-built” in the factory without gaining the benefits of the gang-nailing machinery (Anderson and Anderson, 2007). The height limitation is also another concern when designing wood frame. Some panelizers cannot easily make panels taller than 9 or 10 feet (Anderson and Anderson, 2007). On the construction side, the wood panel typically requires a small crane to lift it up then put into place before connecting it with the other building components, so it will be difficult if the construction does not have enough space to lay down the panel. Even though the overall length of panel is more flexible, it can be up to 45 feet or longer, meaning transportation troublesome. Trucking and transporting the panels can be limited in terms of adding cost to a project. The oversize trucks, which are bigger than the U.S. federal standard width limitation, can be very expensive when using them to transport panels (Anderson and Anderson, 2007).

Overall, using prefabricated wood frames is benefiting many projects in terms of cost and speed. Prefabricated wood frames can be used on a wide variety of building types, including single-family houses, multi-family and mixed-use structures, and commercial offices because they are among the easiest prefabrication systems to integrate into the standard process of the construction industry (Anderson and Anderson, 2007). Wood frames can be easily attached to concrete slab and installed with other elements such as doors, windows, sidings or trim.

2.3.2 Steel framing

After World War I, a lot of countries that had been damaged during the war started to reconstruct their communities. There was demand for residential and commercial buildings all over the world. Many European countries and the United States were looking for a new construction method that could save time and be cost-effective. Many famous European architects like Le Corbusier, Mies van der Rohe and Walter Gropius did some experiments on using steel for construction. Their idea was to use steel as a primary structure for the building as well as an integral part of the design aesthetic (Anderson and Anderson, 2007). Since then, steel construction has become a major part of construction. Because of the advantages of steel in construction such as allowing longer span, taller structure and large openings compared to wood or brick construction, steel has become very popular throughout Europe and the United States and eventually a commonly used material for modern construction worldwide. As stated by Anderson and Anderson (2007), “There were many innovative and experimental projects done in the 1920s and 1930s in both Europe and the U.S. that explored the qualities of steel for its ability to separate structure from enclosure and create open glass-walled building”.

Because steel is a flexible material that can be formed into many different shapes, it is often used to produce parts of buildings; from the small parts of buildings such as nails and building hardware to the bigger parts of building such as columns and beams. Most steel, which is used for construction, is pre-manufactured from an off-site factory.

These prefabricated steel members come in varieties of sizes and sections. A project engineer will determine the sizes and sections of these members, which are mostly the standard sizes from steel manufactures, to accommodate with an architectural design. Building a steel building can be very quick. The process of steel construction is simple. Prefabricated steel structures, which are delivered to the site by the manufacture, can be easily assembled by using bolt or welding methods, which most workers are familiar with. Most steel buildings use steel for only a primary structure which can be called "building skeleton" (see figure 2.7); the other parts of the building can be often seen with other types of materials such as glass, panel or concrete.

Figure 2.7: Steel "Building Skeleton", Premier Inn

(wikimedia.org, 2008)

Steel is often used not only as a primary structure but also as a light structure like purlins or sidewall grits. Purlins or grits are cold-formed "C" or "Z" sections that attach to the primary steel structure. They can be easily attached to either the flange or the web. This light structure steel is often seen assembled at the construction site or it can be factory-assembled as well (Smith, 2010). For the interior building, light-gauge-steel

framing, which is available in North America since 1930, can be used as structure for interior walls (Anderson and Anderson, 2007). This steel stud is used for non-load-bearing wall partitions (see figure 2.8). Similar to grits, the steel stud panel can be either assembled on-site or off-site. As stated by Smith (2010), “Being manufactured as panels in factory allows metal panel system to be quickly erected onsite, saving time and money”. Steel stud, or metal stud, is more reliable than wood stud. It has less deflection and can be very precise when installed. Moreover, using steel as a cladding material gives a modern look to a building. Steel cladding is a prefabricated finishing material that comes in a variety of sizes, surfaces and colors. It can easily be attached to a metal stud or other material.

Figure 2.8: Metal Stud Framing for Non-Load-Bearing

(Truong, 2010)

There are a lot of advantages to using prefabricated steel for construction, but sometimes using steel can add more cost to projects. Using steel can be expensive compared with wood or brick building. This cost can be controlled by either architectural design or engineering design. The more custom-designed steel is, the more cost is added to a project.

2.3.3 Concrete System

Concrete is one of the most commonly used pieces of materials for construction worldwide. In the past, concrete was used only by a cast-in-place method. The cast-in-place concrete comes in a liquid form of mixed-cement which makes it very easy to cast into a desired shape. To help increase its strength, the liquid cement is frequently mixed with sand and crushed stone before it is poured into a formwork at a construction site. Because of its strength and flexibility, concrete is often used as primary material for building structures such as beams, columns, and floor slabs.

In the history of prefabricated concrete, Concrete Masonry Unit (CMU) (see figure 2.9) is one of the oldest type of prefabricated concrete that is used in the United States. It has been introduced to the American construction as a replacement of brick since the early 1900s (Anderson and Anderson, 2007).

Figure 2.9: Concrete Masonry Unit (CMU)

(http://www.conspectusinc.com, 2013)

Since then, the construction technology for prefabricated concrete has been developing rapidly. Precast construction, one of the most popular prefabricated concrete's construction methods, has become a common phase and common method in U.S. construction. "Precast construction is the casting of concrete components offsite in a

plant and shipping to site for assembly" (Smith, 2010). Precast concrete can be used as a structure, which is called "structural precast" (see figure 2.10), or an architectural component, which is called "architectural precast" (see figure 2.11). Structural precast typically refer to a non-finished precast concrete that is left in a standard grey color exposure. For example, the structural precast elements are solid flat slabs, hollow core slabs, double tee, single tee, and precast concrete beams or columns. Those elements are commonly used for both prefabricated buildings and infrastructures such as bridges or tunnels. Architectural precast refers to either structural or non-structural precast that comes with an extra layer of a finish or finishes that cover a standard grey color. There are many finishes available in the market for architects or designers to select, such as brick facing tiles or textures such as aggregate face, acid wash, and sand blast.

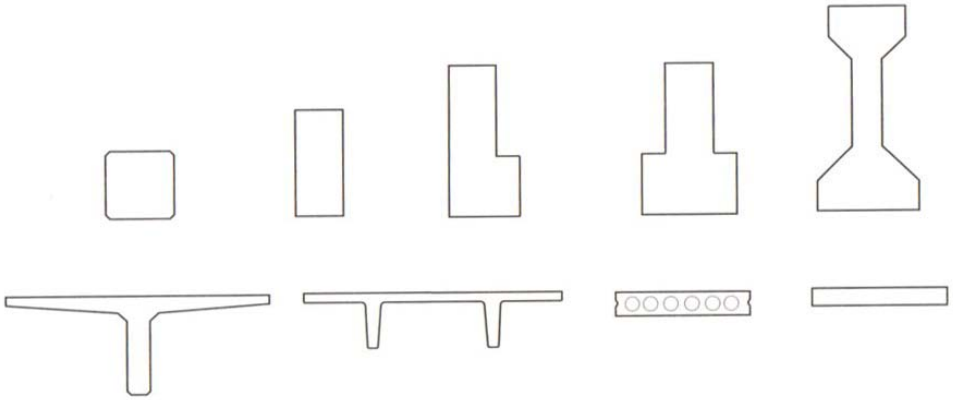


Figure 2.10: Standard Structural Precast Section from Hanson Eagle Precast's Catalog: From Top Left to Right: Square Column, Rectangular Beam, L-Shaped Beam, Inverted Tee Beam, and Aashto Beam Single Tee. Bottom Left to Right: Single Tee, Double Tee, Hollow Core Slab, Flat Plate Slab (Smith, 2010).

Figure 2.11: Left: Structural Precast, Right: Architectural Precast (http://kerkstra.com, 2014)

Generally, concrete has good compressive strength. Many times, structural-used concrete, which can be referred to as reinforced concrete, has to be reinforced to increase tensile strength. Steel bars are often used to add a tensile strength to a reinforced concrete. These bars are tied together before cement is poured on the top at a construction site. Similar to the making of reinforced concrete, a precast concrete panel also uses the same casting method but is only produced in a factory. The welded steel, cross-brace rods, reinforcing mesh and foam insulation are placed in layers before being poured with the Portland cement. As stated by Smith (2010), "Because precast concrete is made in a factory, its process may include adding heat to accelerate the hardening of the concrete and adding moisture for full hydration of the Portland cement and water. Recasting plants are able to produce fully cured elements from laying of prestreesing or reinforcing strands to removal of finished elements from the bed in a 24-hour cycle". This development is not only shortening the curing concrete period but also reducing the labor cost. Therefore, using precast concrete helps reduce construction time and cost.

There are some concerns about weight and transportation when using precast concrete. Although precast concrete is not as heavy as cast-in-place concrete, it is still heavier than wood and steel. There could be more structure cost from its load and transportation cost added to a project. Also, precast weight and size can make it difficult for transportation. A large structural precast section which is larger than the typical section such as a double tee size can be complicated when transporting it. Since the

weight is one of the most critical concerns when using precast concrete, the new technology, such as fiber-reinforced concrete, has been developed to reduce the weight problem. By replacing the labor intensive steel reinforcing bars with short stands of fiberglass, carbon, or steel fiber suspended in the concrete mixtures, this system makes lighter precast concrete. As explained by Anderson and Anderson (2007), “This advance in concrete technology offers potential for much lighter, smaller section panels that can accommodate far more complex shapes and curves and will allow for more mobile and less costly offsite concrete construction”. There are a lot of upsides in precast concrete technology that will help its market grow faster in the near future.

2.3.4 Panel System

The panel system is the most commonly used prefabrication method in U.S. construction. 43% of all prefabricated homes in the United States use the light panel system (Smith, 2010). The use of panels system in the United States can be traced back to the 1930s when Frank Lloyd Wright, designed his Usonian house. The early panel, designed by Wright, was a non-structural panel which did not have a proper thermal control (Anderson and Anderson 2007). Since then, the panels system has become very popular and has been developed with more advance technology. Today, there are many types of panel in the market. The panels can be customized to use either as a structural panel or non-structural panel. As concluded by Smith (2010) “Panels are planer elements used to build structural walls, floors, and roofs, load-bearing or non-load bearing enclosures, and interior partitions”.

Wood panelization and steel panelization are two names that describe the framing of light wood or light-gauge-metal-framed walls produced in a factory. The panelization system is a very popular method when constructing a house or a small commercial building. Panelization not only makes construction faster because of the easy installation method (the completed panel is delivered to a site where workers install quickly compared with onsite framing) but also reduces construction waste from a site. Wood and

steel panelization is generally produced in the factory (see figure 2.12) before being distributed to a construction site. Most contractors and developers like to use panelization because it is a less complicated method, which saves time, money and energy.

Figure 2.12: Wood Panelization

(http://northcoastpackagedhomes.blogspot.com, 2004).

Another popular panel product is Structural Insulated Panels (SIPs). As described by Smith (2010) “SIPs are a sandwich panel used as structural and enclosure and strictly infill enclosure for large steel or concrete frame structures. SOPs are manufactured from varying thicknesses of two layers of oriented strand board (OSB) sandwiching an EPS (expanded polystyrene) or PUR (polyurethane) core (see figure 2.13). In addition to OSB, fiber cement, metal, gypsum board and other materials are beginning to be introduced as sheathing for one side or the other in SIPs”. Most of SIPs’ manufacturers use CAD/CAM technology to produce the panel. The technology helps SIPs to be very precision-cut which makes it very easy when installing. The thickness of SIPs depends on the size of framing. The lengths are based on 2 feet increments (8, 10 or 12 feet) and the widths are always set to 4 feet because of the standard size of OSB sheet which is used to produce SIPs. The layers in between either a PUR foam core or a EPS core perform as insulators and have fire, flame and smoke rating (PUR foam normally has better performance). The

panel also has vertical and horizontal cylindrical chases to accommodate electrical wiring.

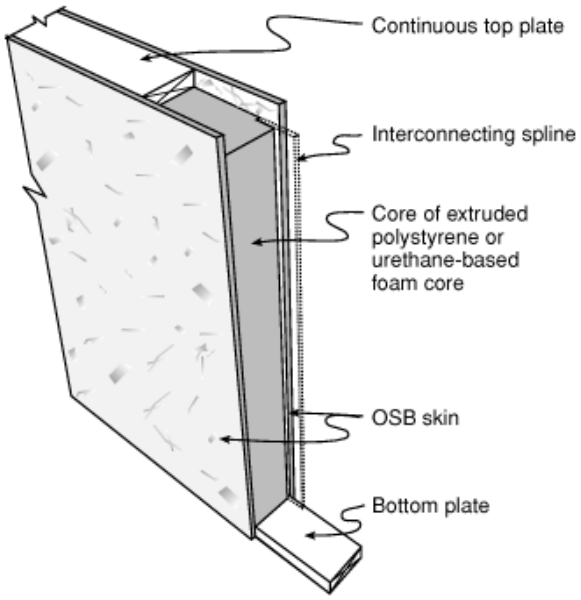


Figure 2.13: Section Diagram of Structural Insulated Panels (http://www.timberframedesign.net, 2013)

When using SIPs, contractors and designers need to know that SIPs are high flexure objects. To reduce deflection when using the large piece of SIPs, the additional strength must be added to help support SIPs. Furthermore, SIPs need to be stored dry and flat at least 6 in. off the ground and should not be stored longer than six weeks. Storing SIPs requires them to be covered with a breathable, waterproof trap and extreme heat can also damage SIPs. Lastly, a crane is necessary to set up the panel which may add up cost to a small project.

Another popular panel system is the curtain wall system. As stated by Smith (2010) “Glass facades, sometimes referred to as curtain walls, are exterior non-load-bearing transparent or translucent enclosures”. The curtain wall system has become a very popular system throughout the world. Because of the modern look of a building when using curtain wall, it is often seen as a commercial building. Examples include

offices and hotels or multifamily residential buildings such as condos and apartments, but we can also see many single family houses using the curtain wall system. The curtain wall system is an assembly of glass and aluminum frame. There are differences in the degree of prefabrication when referring to its systems. The two most common systems for curtain walls are the stick system and the unit system. The stick system refers to a method by which the pieces of aluminum are assembled onsite before the prefabricated insulated glazing unit is installed. The unit system has a higher degree of prefabrication. It comes in the unit, prefabricated glazing and aluminum frame, and is assembled in the factory. It is a very precise system and easy to install. The negative side could be that the cost of curtain wall is very expensive compared to other panels systems.

2.3.5 Modular System

The modular system is the most completed prefabrication system. As stated by Anderson and Anderson (2007) “The term *modules*, in the world of architecture and construction, has often been used to refer to largely completed or whole sections of buildings built at a factory and trucked to a site for quick deployment”. The modular system not only provides the whole exterior skin (walls, windows, doors, floors and sometimes roofs) but it also comes with a mechanical system, interior finishes, and fixtures such as toilets. It is very common to see the whole completed modules for residential buildings that have all the rooms, such as the bedroom, the living room, the kitchen, and the toilet, attached to it, but the individual parts of a house like the toilet and the kitchen are also available as modular. Generally, the units are built in a factory then delivered to a construction site. At the construction site, workers use large cranes to lift the units up (see figure 2.14) then stag them on top of each other.

Figure 2.14: Modular Unit's installation process

(http://www.kodumaja.ee, 2012)

In the past, the modular system was designed to use as a short-term building. Many contractors used shipping containers as site-offices, but now, since the construction technology has been rapidly developing, the modular system is a common use for many types of buildings and larger scale buildings. The life-long building products have replaced the use of temporary material on a modules building, which makes its life-span much longer. Many new modular buildings are still used as temporary buildings but the use of concrete and steel makes the life-span of modular building expanded longer, which more often, makes those buildings more like permanent buildings.

In the United States, the modular system has been used in both residential and commercial markets. The majority of modular buildings in the United States are residential buildings. The modular unit is often used for permanent or temporary homes. Many times, because temporary modular homes can be easily taken down from one place and reassembled in other place, they are considered as mobile homes. Since the large modular units are very difficult to transport, most of the modular home markets target a small housing market or an affordable housing market. The larger size of a residential

modular building tends to be a multifamily residential building. Apartments, hotels and dormitories, are usually multi-story buildings which often build their primary structures separate from the modular units. As states by Smith (2010) “The tallest modules project to date in the United States is the 1968 Hilton on the Riverwalk, in San Antonio, built from precast modules. The hotel is four lower stories of site-cast reinforced concrete. Floor 5 through 21 are constructed from precast modules”.

There are varieties of materials which can be used to produce modules units. During the 1960s, the primal modules units were commonly built in wood. Most of its components that include floors, wall panels, and roofs, were made of wood. This modular system is frequently used for a residential building because it usually comes in a smaller modular comparing with steel modular, and this system is also cheaper. On the other hand, the steel modular system is primarily used in commercial buildings that are mostly taller and larger than residential buildings. The steel module usually comes in a bigger modular system which often requires a bigger crane to assemble. Because most commercial buildings typically have more budgets compared with residential buildings, they can absorb additional costs, such as transportation cost and cost from renting a bigger crane.

Although the modular building is referred to as a completed building which is shipped from the factory, the oversize modular unit is transported in pieces. Some of the modular buildings can be separated as big pieces such as building and roof to make the unit’s size smaller when transporting them (see figure 2.15) but many times modular buildings are separated into smaller components. As explained by Smith (2010) “Knock-down methods refer to roofs or panels built in the factory, flat packed and tilted, or propped up and erected onsite”. In concept, this type of modular system may look similar to penalization or “House by Mail”, but the difference is that the modular company performs the fabrication and erection process.

Figure 2.15: Modular home roof components

(http://www.nihb.com, 2008)

The modular system is the quickest way to build a building because 90-95% of the construction process is done at the factory. Using the modular system can save a lot of time and money. The modular unit is typically built or designed using a standardized system and dimension which makes it easy to mass produce. In contrast, the modules system is less flexible in term of design construction. Oftentimes, because buildings are pre made, they are very difficult to modify or change the design which results in many repetitive look of buildings.

2.4 CONSTRUCTION TYPES

The prefabrication system is designed to build faster and more economically. The advantage of using the prefabrication system is that the more repetitive or standardized the buildings are the more profit they generate for projects. In the United States, every building is controlled by building codes, terms and regulations, from municipal restrictions to federal laws. Compared with other buildings in Asian countries, the buildings in the United States tend to have more restrictions. There are many factors such as safety both during the construction and after the construction, energy concerns, and concordance in a neighborhood that affect both the building design and the construction,

which results in more standardized buildings. For example, the building's setback, the standard wall thickness, the thermal and fire protection, fire stairs, the standard parking deck or small things like the height of guardrails and handrails are controlled by U.S. building codes. Although these controls limit the flexibility of the design, they benefit the prefabrication market.

2.4.1 Single-Family Residential

In the United States, the majority of homes are built by builders, and then those houses are sold to home buyers while only a small percentage of houses are custom-designed. Unlike in countries where architects and engineers offer lower design fees, hiring architects and engineers in the United States can cost a lot of money to future home owners. Most Americans choose to buy homes from developers' catalogs or homes that already exist in the market. Therefore, the U.S. housing trend is influenced by developer and builder rather than architects and designers. Since the common goal of every developer and builder is to build faster and more economically, because this strategy will save them from paying more construction loan's interest, prefabrication for the residential market is a perfect choice. "According to *Automated Builder*, a magazine that monitors the construction industry's use of prefabrication in housing, 56 percent of all residential construction in the United States is manufactured, modular, and panelized in technology" (Smith, 2010).

Single-family residential typically refers to the two categories of housing types: single-family detached and single-family attached. Single-family detached homes generally use less prefabrication method compare to single-family attached homes. Because single-family detached homes vary in size, area (building square footage), floor plans (number of bedrooms, bathrooms), whether they are built in a community or in individual lots, they seem to be more custom built from project to project; many of them have partial prefabrication. Although single-family detached homes in a community tend to use a similar specification, they typically have a variety of floor plans.

Single-family attached homes include duplexes, triplexes, or fourplexes. This type of residential building generally has the same floor plan (many times, they are mirror floor plan as shown in figure 2.16) for each unit which receives a lot of advantages when using prefabrication.

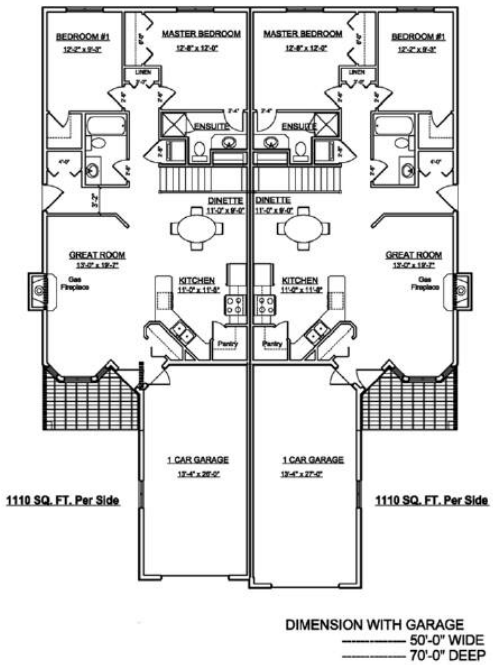


Figure 2.16: Duplex home's floor plan

(http://www.edesignsplans.ca, 2008)

2.4.2 Multifamily Residential

The multifamily homes can be seen as a low-rise such as townhomes, mid-rise or high-rise condominiums. Although a townhome has similar concept to a single-family attached home, it has various floor plans and sometimes, it may has different design on the exterior such as façade and roof to create more options for the buyer (see figure 2.17). Still, a townhome benefits from prefabrication since most of its units normally have the same depth and floor-to-floor height, the floor plans are not much different. The mid-rise and high-rise residential buildings seem to have the most benefit from prefabrication. Because these buildings are mostly designed to have many repetitive components such as

exterior façade, which typically are precast concrete walls or curtain walls, unit types or floor to floor height, mid-rise and high-rise developers can easily reduce their construction cost by using prefabrication.

Figure 2.17: Lafayette Square Townhomes, Sandy Springs, Georgia (http://equity1team.com, 2012)

2.5 PREFABRICATED CONSTRUCTION MARKET IN THE U.S.

2.5.1 Existing Market

After World War II, the prefabricated construction market in the United States grew rapidly. In the beginning, the prefabrication market focused mostly on a single family home's market. Today, the market has expanded to other building industries that include healthcare, education, and commercial buildings. About 85% of respondents are using these strategies to design and construct those commercial projects at some levels (Smart Market Reports: McGraw-Hill Construction, 2011). Still, the largest prefabrication market is the housing market. Most homes in the United States are built as prefabricated homes. As described by Smith (2010) "Prefabricated housing can be categorized into modular, mobile (HUD code), production builder, and panelized. "Below is the market share"

- 63 percent of all new housing is being built by builders/dealers.
- 56 percent is panelized.
- 33 percent production is onsite building.
- 7 percent is modular.
- 4 percent is HUD-code mobile.

The panelized system is the largest market for home builders. In 2008, the estimated 3,500 panelizers collectively built just over a million units while 622,000 units of production builders and 127,000 of modular homes were sold in the same year. The production builders use only partial prefabrication such as primary structures for their projects. Most of them use factory-fabricated roof trusses and many of them use other components of prefab such as floor trusses and wall panels (Smith, 2010). These three categories of prefabrication (panelized, production builders, and modular) seem to be the most popular prefabrication for single family homes these days since the site labor and construction loan costs are skyrocketing. However, the prefabricated home industry has been facing the down-turn because of the subprime mortgage crisis that started in 2007. With the housing prices for traditional on-site constructed homes down, the demand for prefabricated homes has also declined. Revenue has declined at an annual average rate of 9.2% from 2007 to 2012 (Prefabricated Home Manufacturing in the US: Market Research Report, 2012). Nevertheless many developers still see prefabricated homes as the future and since prefabricated system has been a very successful system for residential construction in the U.S., it also has potential to be very successful in Thailand.

2.5.2 Future Market

The future market of prefabrication can be seen as the development of the existing market and the new construction trend market. Initially, the prefabrication's concept was a method of building faster and more economically. The early prefabrication projects mostly were affordable projects such as affordable homes because early developers tried

to catch up with the high housing demand with a highly efficient way of construction. Today, prefabrication is not only being seen as a construction method for affordable projects but it has also expanded into the luxury market. As stated by Furuto (2012) “Modular design and construction will allow the developer to produce higher quality housing at more affordable costs. But the project is equally about using technology to make a more sustainable, more economic, and higher quality product, which can produce a range of buildings – not only affordable housing, but also soaring office towers and luxury co-ops and condos”. Producing high quality building components from a factory is very common these days. Since the technologies of mass production for consumer products have developed very fast, these technologies can help increase the quality of building components to a higher standard.

Figure 2.18: SHoP Architects’ 32-story modular building in Brooklyn New York. *(*Furuto, 2012*)*

The size of building is also getting larger. While land is getting more and more expensive, especially in crowded areas like Manhattan, buildings are getting taller. Although building skyscrapers is not new to prefabrication, it hasn't been very popular. However, there are developers who are interested in building luxury prefabricated high-rise in an expensive land area. One of the good examples is a new 32-story modular building in Brooklyn, New York, designed by SHoP architect (see figure 2.18). As explained by Furuto (2012) "Modular construction is in use in various forms around the world. It is rarely used however for high rise development, even though it is perfectly suited for conditions where space is tight and land values are high — which is what makes its use on this project unique and particularly relevant to New York". Since many developers are interested in using prefabrication for high-rise buildings, there should be more prefabricated high-rise buildings in the near future.

The new construction market trend also impacts the future of prefabrication. These new construction trends, Lean Construction, BIM, and Green Building, are influenced by the development of construction in different aspects. Lean construction has become popular for many contractors these days. The concept of lean construction is to reduce construction waste from both ends. As stated by Koskela (2002) "Lean construction is a way to design production systems to minimize waste of materials, time, and effort in order to generate the maximum possible amount" of value". Although lean construction is not a new invention, its fashion has impacted the use of prefabrication. Producing building components from the factory has always reduced more waste when compared with on-site construction (see figure 2.19). This concept has forced more contractors to use more prefabrication.

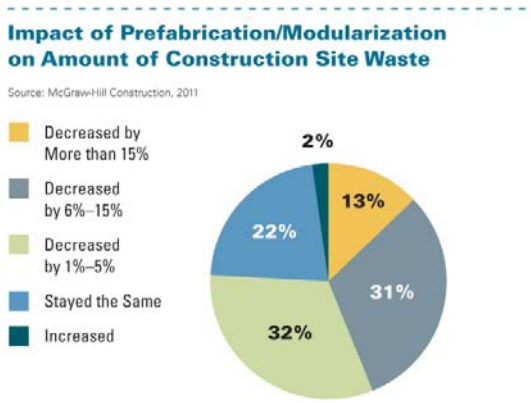


Figure 2.19: Impact of Prefabrication on Amount of Construction Site Waste.

(Smart Market Reports: McGraw-Hill Construction, 2011)

The use of BIM has become more and more common in the United States (see figure 2.20). There is a greater demand of BIM by owners as they work on their projects. As described in the McGraw-Hill Construction's report (2011) "McGraw-Hill Construction (MHC) found that the use of BIM model-driven prefabrication on more than one quarter of their projects is expected to increase from 37% to 73% among practitioners who use BIM for green work". BIMs and prefabrications are a perfect match. While the BIM model helps a lot on the production side, BIM helps designers to see more clearly before constructing.

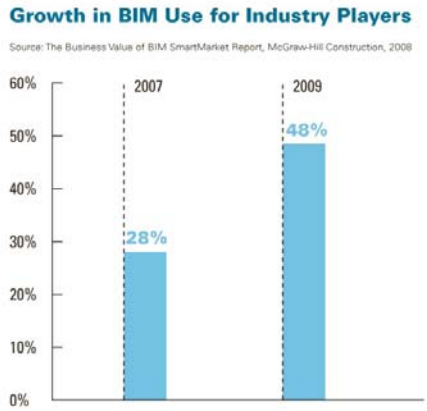


Figure 2.20: Impact of Prefabrication on BIM

(Smart Market Reports: McGraw-Hill Construction, 2011)

Green Building has played a big role in American construction for decades. In 1998, U.S. Green Building Council (USGBC) introduced the LEED system that affects overall construction in the U.S. The LEED system established the rating system for design and construction. Using prefabrication can help contractors or designers to calculate the LEED's rating system easily because those building components that come from a factory typically show the rating calculation, and they are very precise. Not only do many prefabrication building components would make it easy to earn the LEED's credits, but they are also designed to be green materials as shown in figure 2.21. For example, the panelized system is designed as an energy saving system

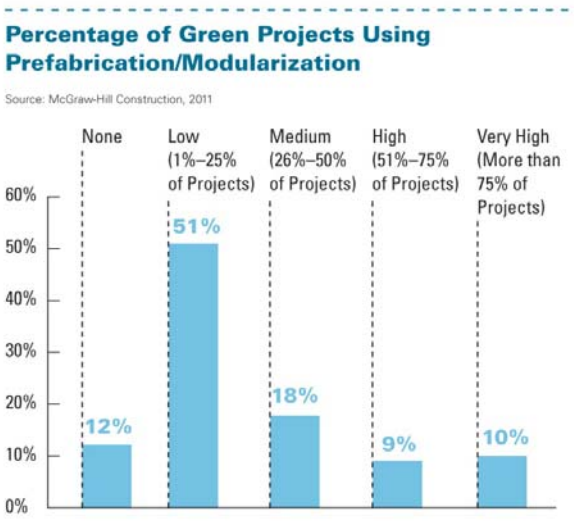


Figure 2.21: Impact of Prefabrication on Green Projects

(Smart Market Reports: McGraw-Hill Construction, 2011)

By researching the existing market and the future market in the U.S., people now can compare them with the existing market and future market in Thailand. The existing market in the U.S. proves that prefabrication has been very successful in the U.S, the country that can produce a high standard construction with less labor expense, and the future market helps projecting the potential of future Thai market in the current construction trends, such as lean construction, BIM technology, and sustainable.

CHAPTER 3

REAL ESTATE & CONSTRUCTION IN THAILAND

3.1 OVERVIEW OF REAL ESTATE IN THAILAND

From the 90s, Thai society has been transformed from agriculture society to white collar profession society. People from the suburb and country side have moved to big cities such as Bangkok, the capital city of Thailand. Many farm workers have transformed into small business owners. Although big cities in Thailand like Bangkok haven't had the demand for office buildings in the past ten years, the demand for multifamily residences in Bangkok have grown significantly in the past five years. Besides the booming economy in Asia, another reason why the condo market in Bangkok has been very successful is that Thai government started to invest in a mass transit system. In 2001, the first Sky-Train (monorail) started its service in Bangkok. Since then, there have been many expansions of the Sky-Train's lines and subways in Bangkok. The introduction of the mass transit system in Bangkok has had a big impact on the Thai construction business especially on the residential side. In the past five years, hundreds of condos have been built in Bangkok along the Sky-Train's lines and its stations. The empty lots in the suburb area, which are projected to be the place where the new train lines will be constructed, were bought and are planned to be new residential communities. In the country side, the Thai government is trying to reduce the high population density in Bangkok by distributing the budget to the major cities in the provincial part of the country. Many airports and infrastructures were built in the countryside area, plus the Chinese government has announced a mega project, the China-ASEAN high speed train project, that may change the overall image of Asian business (Menz, 2012). The train line is planned to be constructed from the southern part of China

through Singapore which will cross seven ASEAN countries including Thailand, Myanmar, Laos, Cambodia, Vietnam, Malaysia, and Singapore.

Today, the price of land in Thailand has increased more than 30% from two years ago in many areas. In some areas in Bangkok, the investor can see the price jumped to as much as 100-200% which most of them are the areas where the sky-train stations are built. The Thai government has projected a high volume of construction during the construction of the rail and after its completion. There will be a high demand of housing and construction in the country side of Thailand in the near future, as seen in figure 3.1.

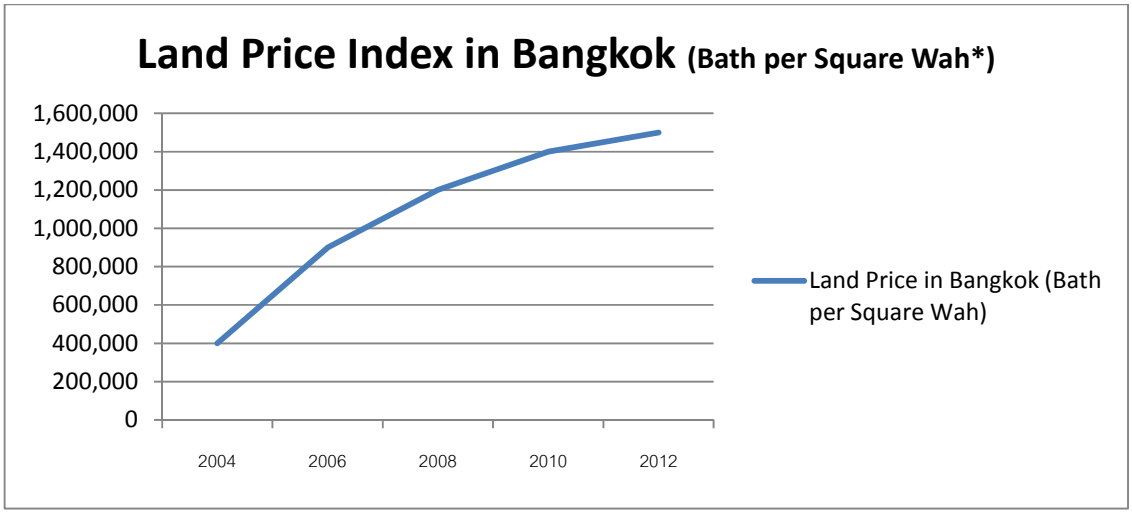


Figure 3.1: Land Price Index in Bangkok from 2004-2012. The price is based on the price of lands which are sold. (Bath = Thai Currency, Square Wah = Thai Measurement)

(CB Richard Ellis, 2012)

3.2 CONSTRUCTION METHODS IN THAILAND

The residential sector is the largest construction sector in Thailand, just as it is in the U.S. Although contemporary Thai houses look more like western houses, the Thai construction method for housing is different. Approximately ten to fifteen years ago, the labor cost in Thailand was a lot cheaper than it is today. At that time, the Thai construction method depended on cheap labor cost. “Post and beam” is a typical method

for building houses in Thailand. The typical process starts from drilling holes to install concrete piles then pouring concrete footing on the top. The next step is to create structural beams and floors which are normally cast in place concrete. The exterior and interior walls are made from red bricks or foamed concrete block (see figure 3.2) (foamed concrete block is lighter and larger than normal red brick) then covered with finished cement. Roof structures are also made from concrete. The roof beams and rafters are typically seen using cast in place concrete with clay or cement roof tiles for roofing material. It may take up to 18 months to build a small size house (2 stories with approximately 150-200 square meters) through this process, which also requires a lot of workers.

Figure 3.2: Post and beam with red brick & Foamed concrete block (http://www.websales.torhome.com, 2013)

Although Thailand has a hot climate throughout the year, it has four months of rainy seasons. The rainy seasons always slow down construction especially the cast in place process; pouring concrete is often stopped during storms. The rain also impacts the quality of concrete such as concrete beams and rafters, and it also increases the moisture level of cement inside brick walls. Problems such as cracks between the connection of rafters and beams mold inside brick walls are often seen in this type of construction.

From past recent years, the labor cost in Thailand has been rising. From 20111 to 2013, the Thai minimum wage has doubled (see figure 3.3). Many developers and

contractors have tried to reduce the labor cost by researching new technology. The early stages consist in replacing cast in place concrete structure or, skeleton structure, with prefabricated steel for roofing structures, using prefabricated concrete columns and beams, installing steel framing and dry-wall for interior walls rather than using red-brick walls. The next generation is the beamless skeleton structure. This method will replace the use of cast in place concrete beam by placing pre-stressed concrete floor on the structural concrete columns. These methods are very effective and can quickly be spread from the city to the country side.

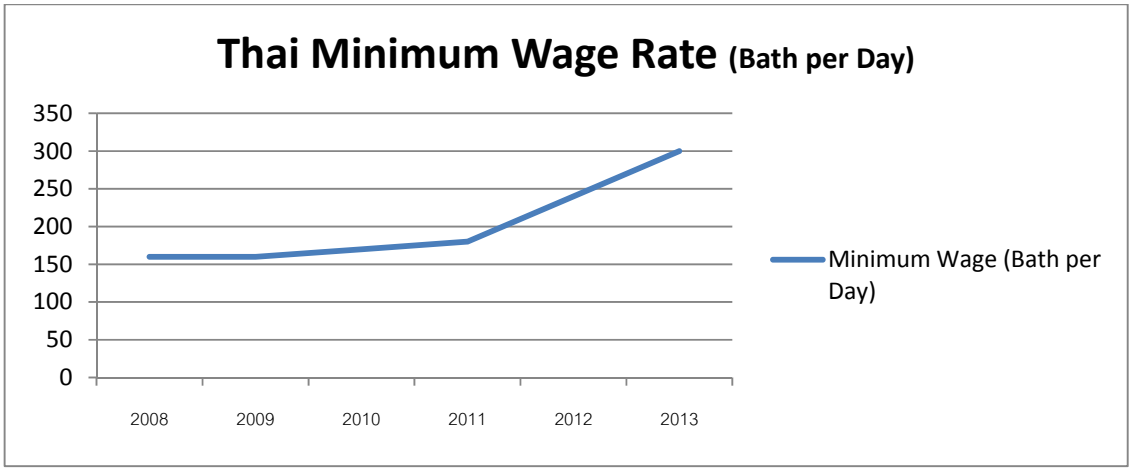


Figure 3.3: Thai Minimum Wage Rate (Bath = Thai Currency)

(Thai Ministry of Labor, 2014)

CHAPTER 4

PREFABRICATION IN THAILAND

4.1 HISTORY OF PREFABRICATED CONSTRUCTION IN THAILAND

Although prefabrication has been used for construction in Thailand for more than twenty years, it was not very popular until the past five years. Back in the 80s, prefabricated concrete and steel were used only for large construction such as bridges and highways. The late 80s, was a time when western architectures had influenced the architectural style in Thailand, it also was the time of the booming of white collar jobs. Many office buildings were built using prefabricated curtain wall systems. Later on during the early 90s, the housing development market in Thailand rose because of the high demand from white collar people. They were thousands of communities and hundred thousands of new houses that were built inside metro Bangkok. Most houses were built using the post-beam and red-brick construction while only few of those houses were built using prefabricated walls. The early prefabrication types that were used during the 90s in Thailand were gypsum board on stud walls, prefabricated window wall systems. Those prefab walls and windows were not successful because most of the contractors did not have enough knowledge in prefabrication methods and had difficult times adjusting to the system, plus the other factor such as the preciseness of construction in Thailand was very limited. The onsite installation caused a lot of problems to both contractors and developers which resulted in project delay that cause more money.

The Asian financial crisis in 1997 impacted the construction business all over Asia. The crisis, which started from Thailand, pushed the construction business in Thailand to the bottom line. There were a lot of abandoned communities and many mid-rise and high-rise building all over Bangkok. After the crisis, the construction business in Thailand slowly grew. Since 2000, there has been significant increase in volume of

construction in many sectors such as residential, commercial, health care and hospitality. To absorb the growing market, Thai developers had to build more and faster. Some residential developers looked at prefabrication. During years 2003-2005, the return of prefabrication construction targeted affordable housing and small units such as townhomes. There were a number of new affordable homes that were built from prefabricated methods. Pruksa, a community home builder company, was the first company that started to focus on using prefabrication. At the beginning, Pruska started using prefabricated concrete for its townhomes. At that time, Pruksa's homes received a lot of negative criticism from competitors because prefabrication was not very successful in Thailand 20 years ago. However, it was a jump start on the building business for Pruksa. The sale of Prukas's townhomes was significantly increased and Pruksa has become one of the very successful in the precast business. Although the early prefabricated townhomes by Pruksa were not fully prefabricated, they were very successful in term of budget control and construction schedule.

Since then, many housing development companies have tried to use more prefabrication in their new projects. Prefabrication gives a new perspective to home buyers because they can see the finished houses before they commit to buying them, while in the old market, home buyers always had a difficult time imagining how home looked from an architect's rendering. Although the cost of prefabricated homes is a little higher than typically skeleton structures, approximately 3% for 100 square meter home, they can be done faster approximately by 35% of the total times (Limthongtang, 2005). Currently, big construction markets in Thailand that use significant prefabrication are such single family homes, from affordable home to mid-range prices, townhomes, low-rise, mid-rise and high- rise condominiums.

4.2 TYPES OF PREFABRICATED CONSTRUCTION IN THAILAND

Prefabricated construction in Thailand, especially residential construction, has a very long history. Briefly, the traditional Thai house is considered as an early type of prefabricated house. Without nails or screws, tradition Thai houses are constructed by using the “interlocking system”, a technique that holds primary structures such as columns, beams, rafters and secondary structures such floor joists, walls, and roofs by interlocking them together. Today, traditional Thai houses are available for sale such that a buyer can order them from the catalog. The seller will deliver the components of the house to a construction site and most of the time the seller will also assemble them. However, traditional Thai houses are more like a pavilion. These houses do not have other housing systems such as electricity or plumbing that come with them. The owner will need to install those systems after the houses are completed or during construction.

The next generation of housing in Thailand came after the colonization period. Houses in Thailand have been transformed from pure wooden houses into brick and glass houses because of Western influences. Those Thai houses also looked different from the traditional Thai house which was often seen as a wooden house with a high pitch gable style roof to have more western looking. This Western-style house makes it easier for western construction technique is applied such as prefabrication.

Although Western-style prefabrication has been used in Thailand for more than fifteen years, many Thai contractors still have limited knowledge on the different types of prefabrication. When Thai contractors refer to the term precast, they refer to a precast concrete panel. Currently, there are some different types of prefabrication in Thailand that can be seen on the market.

4.2.1 Prefabricated Concrete

The early prefabricated concrete construction in Thailand was only used for heavy construction such as bridges and highways, but when the housing market in Thailand raised many Thai developers and contractors started to see more potential from using

prefabrication. The prefabricated concrete systems for residential buildings in Thailand can be categorized into two systems: 1) Prefabricated Concrete for Single-Family Homes 2) Prefabricated Concrete for Multifamily Homes.

4.2.1.1 Prefabricated Concrete for Single-Family Homes

Prefabricated concrete systems have become increasingly popular for a mid-size home market. This system requires a lot of input on design process to arrange the pieces of the panel into an architectural design. Developers must make a decision that they want to use this system before the design process begins. The concrete panels that are used in this system are designed to match building elevations. Those concrete panels are produced inside the factory. They come with window opening, electrical and plumbing pipe inside the panels. This system is designed to be a wall bearing system. Because the concrete wall of the prefabricated concrete system is a main structure, the thickness of the panels is 15-20 cm which is thicker than the typical brick wall. The height is between 3-3.5 m. which is the height of one floor (see figure 4.1). This system can reduce construction time onsite for mid-size home (approximately 150-200 square meters) from 12 months to as few as 4-5 months (not including the production time of each panel in the factory). Today, most large residential developing companies have used the prefabricated concrete structure rather than the skeleton structure. Construction method and photos can be seen in appendix A.

Figure 4.1: Prefabricated Concrete for Single-Family

(Author's photo, 2013)

4.2.1.2 Prefabricated Concrete for Multifamily Homes

This type of prefabrication is normally used in mid-rise and high-rise residential towers. Unlike the single-family home system in which the panel works as the main structure or wall-bearing system, the multifamily home system is used as building façade that does not help transform the load, instead the concrete panel is attached to the skeleton structure (post and beam) which is the main building structure. The panels are designed by architects or structural engineers to match the building elevations. The size of the panel is generally equal to the height of a floor to floor (3-4 m.) and the width is equal to the span of the building (5-6 m.). The thickness of this panel is approximately 15-18 cm. depending on the size of the panel (some projects use panels as thick as 25cm.). This panel also comes with openings and embedded steel plates (see figure 4.2).

Similar to the single-family system, the concrete panel for multi-family home is produced from the factory then delivered to the construction site. The precast factory claims that each mold can produce up to thirty panels which is a breakeven point before it

is destroyed, so it might not be worth to build a small building (less than eight stories) with this type of panel because the cost of each panel could go up significantly. Construction method and photos can be seen in appendix B.

Figure 4.2: Prefabricated Concrete for Multifamily

(Author's photo, 2013)

4.2.2 Modular System

The modular home in Thailand had never been as popular as it has been in recent years. There are several products of modular home available in Thailand, from a small container to a 400 square meter home.

4.2.2.1 Knock-Down House

Some small builders in Thailand have come up with a very cheap way to build and sell modular houses. The knock-down house is known by Thai people as an affordable small-size house that is either assembled from the factory before being transported to a site or factory-prefabricated housing components that are transported to a site before being assembled (see figure 4.3 and 4.4).

Figure 4.3: Example of Knock-Down Home

(www. http://thaimobileunit.com, 2013)

Figure 4.4: A knock-down home transported by a light-truck

(www. http://thaimobileunit.com, 2013)

A knock-down house is built from cheap materials such as wood or metal studs with cellulose-cement plank on the exterior finish and wood or light steel structure for the floor and roof system. The average sale price of the house is between $250-300 per square meter ($23-28 per square foot) with an average size between 30-100 square meters. Most people use knock-down houses as temporary habitats in the garden or a

small coffee shop; however, the knock-down house is also used as a permanent home for low-income people. However, these types of house do not have a building code to control them, so most of them are informal houses. There is no guarantee on the quality or the safety of this product.

4.2.2.2 Steel Frame Modular

The upscale modular product that is currently available on the Thai market is the steel frame modular home. There are several mid-size builder companies that offer this type of modular home. The two leading companies in steel frame modular are Bann-Lae-Suan and LYNN.

Baan-Lae-Suan is a leading publishing company which specializes in home and garden. In 2011, the company launched a new project called “Baan-Lae-Suan Modular”. Baan-Lae-Suan Modular is a factory-built home that is built from available materials that already exist on the market such as steel frame, drywall and concrete panel. Most of its components are provided by the company’s partners. Baan-Lae-Suan Modular uses steel frame as its primary structure. The floor is made from a prefabricated concrete panel. Buyers can select the exterior finish from materials available on the market. The finished materials, for example, are fiber-cement plank, concrete panel or any other finished products that can be attached to the steel frame. The interior walls are made from drywall and stud systems. The house also comes with sanitary, water and electric systems that are assembled with the house in a factory. The onsite assembly can be done in approximately one hundred days after the foundation is finished.

Baan-Lae-Suan Modular offers a wide range of houses from a small size, 16 square meters (this small house normally uses in an expansion project), to a large size two-story, 180 square meters. The price range is between $700-950 per square meter ($65-90 per square foot). The greatest advantage of Baan-Lae-Suan Modular is the flexibility of the floor plan. Baan-Lae-Suan Modular has a design team to help buyers modify a floor plan to fit their needs (see figure 4.5).

Figure 4.5: Example of Bann-La-Suan Modular Home

(http://www.baanlaesuan.com, 2013)

Just like Bann-Lae-Suan Modular, LYNN offers a similar product called “LYNN Cabin”. LYNN is a part of Repro House of Thammasorn Group, a company that provides the solution for architectural engineering and produces door & window products. The difference between the two is that LYNN Cabin is available only in three different sizes, 60 sqm, 75 sqm, and 120 sqm (two stories). The house can have a variety of finishes but the floor plans are fixed; in contrast Bann-Lae-Suan Modular has more selection on floor plans and sizes. Because LYNN originally started as a Window & Door Company, LYNN Cabin tends to have more glass façade than Bann-Lae-Suan Modular (see figure 4.6). This will bump up the price of LYNN Cabin up to 15% more than the price of Bann-Lae-Suan Modular.

Figure 4.6: LYNN's details & transport

(http://www.lynn.co.th, 2013)

4.2.2.3 SCG Heim

SCG (Siam Cement Group) is the largest cement company in Thailand. SCG not only produce cement but also provides varieties of construction products and services. In 2010, SCG launched a new product called SCG Heim. SCG Heim is a smart modular home whose technology is imported from Japan. However, Heim's technology originated from Germany (Heim means home in German), but it was modified by Sekisui, a Japanese company, to suit the Asian environment.

SCG Heim is a factory-built home. Approximately 80 percent of its components are built at the factory. The big advantage of SCG Heim, compared with a traditionally built home, is the speed by which it is built. Buyers can expect to move into their SCG Heim as early as four months from the day that they sign a contract. The four-month process is a building process which happens mostly in a factory. It only takes two to three days to assemble the house on site, depending on the size of the house and the location. Figure 4.8 shows an example of SCG Heim.

The strength of SCG Heim is both the speed in which it gets built and the good thermal and sound resistances it has. Thailand is a very hot and humid country. The average temperature during the summer is between 30-40°C (86-104°F). The thermal control for a Thai house has become a big concern for any new development. SCG Heim

uses a double-wall system (see figure 4.7) which is generally two layers of smart boards (drywall) with a gap filled with insulation in between the walls. With the double-wall system, SCG claims that the system can help reduce the use of air conditioning for up to 25 percent. Although the double-wall system seems to be a common system in the U.S., it is still new and not widespread in Thailand.

Figure 4.7: HEIM's wall & window systems

*(*http://www.scgheim.com, 2013*)*

The big drawback of the Heim is that the price per unit is a lot higher than that of a typical brick home. The sell price per square meter is between $900-1,200 ($85-110 per square foot) which is approximately 30-40 percent more expensive than a traditional brick home and 20-30 percent more expensive than the prefabricated concrete home.

Figure 4.8: SCG HEIM, completed

*(*http://www.scgheim.com, 2013*)*

4.2.2.4 Other Products

Some modular home products, such as MYH from Aidol, have unique designs that are only advertised for a smaller market (see figure 4.9). MYH, modular home, has a very slick modern looking design, unlike any other modular products on the market. MYH is designed to be very flexible and easy to transport. MYH is available in many different sizes. MYH uses the same concept as a “LEGO” toy. Buyers can choose to buy MYH as a single unit or a combine unit. MYH’s units can be easily added or removed.

The MYH's developing team claims that MYH's unit can be placed in any surface without installing a foundation or support. MYH's units are not only popular for residential areas, but many buyers use MYH's units in commercial areas as well, as shops, or small resort hotels.

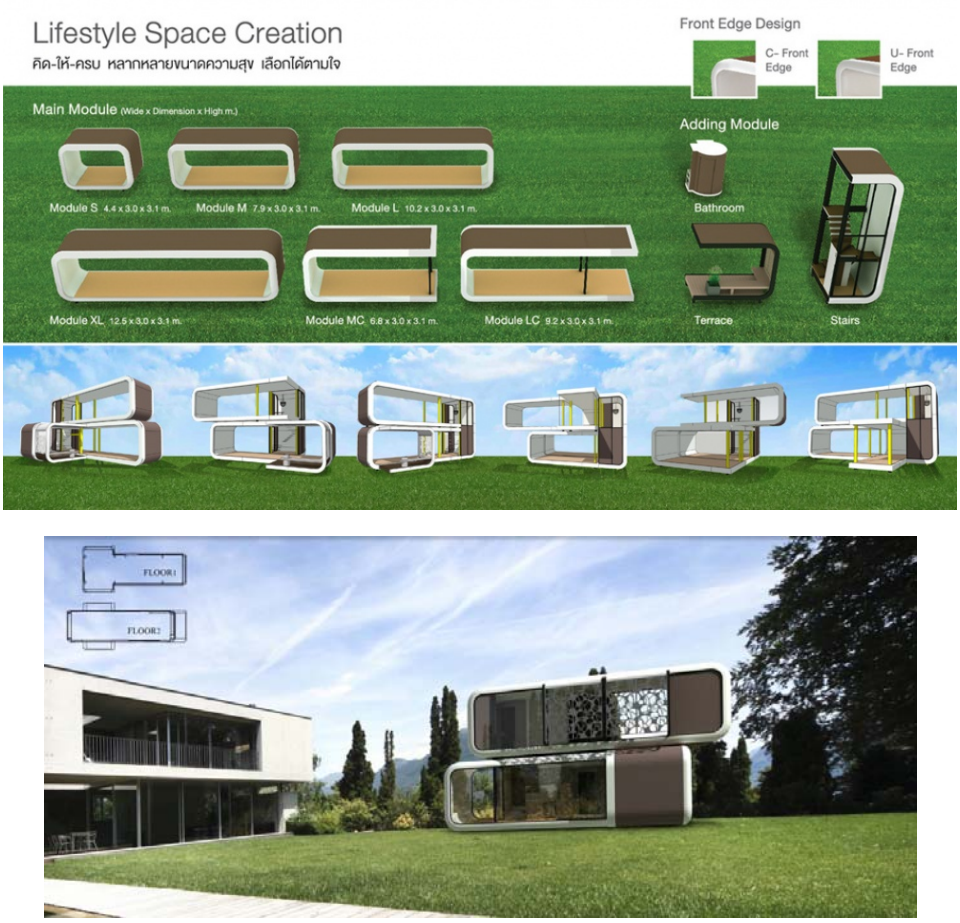


Figure 4.9: MYH's concept & products

*(*http://www.aidolmyh.com, 2013*)*

4.3 PREFABRICATED CONSTRUCTION MARKET IN THAILAND

4.3.1 Existing Market

The real estate business in Thailand has grown rapidly in the past 10 years. The major components that have pushed the business to grow are immigration policies, and foreign investments. Those factors have forced the Thai government to invest more in hi-

tech infrastructures such as sky-trains and subways in Bangkok, and basic infrastructures such as roads, electricity and water lines in the country side. The total value of construction in Thailand in 2011 was approximately $25,000 million, which was an increase of 9.1% from 2010 (www.buildernews.in.th, 2013). Prefabricated construction still does not grow much in the overall construction, although, prefab market has grown more in the residential sector.

4.3.2 Market Research

The Association of Southeast Asian Nations (ASEAN) plans to launch the ASEAN Economic Community (AEC) agreement in 2015 to help strengthen the economy of South East Asian countries. Thailand is projected to be the business hub for ASEAN. The new immigration plan allows people to travel freely between the member countries. This new policy has created more and more demand for housing and has raised home prices in Thailand. According to the Bank of Thailand, the country's central bank, the home price in Thailand has skyrocketed in the past five years. Since 2008, the single-detached home price index has increased by 11.5% while the townhouse price index has increased by 21.3%, and by 41.7% for the condominium price index (see table 4.1). This event will attract more foreign investors because the higher home price can absorb more cost from foreign technologies and could see a faster return in investment.

Table 4.1.House Price Index from Bank of Thailand (Base Year: 2008)

Type	2013	2012	2011	2010	2009	2008
Single- Detached House	111.5	105.8	104.5	101.4	100.4	100
Townhouse	121.3	112.9	109.8	103.7	100.5	100
Condominium	141.7	134.5	127.1	115.9	113.7	100

(Bank of Thailand, 2014)

However, the prefabricated home has not been a major part of the Thai residential market yet. The current market share of the prefabricated home is less than 30%, but the

new minimum wage has gone up to 40% more than it was a few years ago. This has impacted the overall labor market and construction business. In November 2013, Krungthep Thurakit Newspaper reported that many big Thai developing companies felt that prefabrication could help absorb the big labor cost increase from the new minimum wage policy (Krungthep Thurakit, 2013). Mr. Rutt Phanijphand**,** chairman and executive director of Quality House, one of the largest developing companies in Thailand, told Krungthep Thurakit that the company planned to expand its prefabrication market in the single family (both detached and attached) at low price levels (lower than $100,000) and medium price levels (from $100,000 to 250,000), from 30% to 100% prefabrication in 2015. Mr.Atip Bijanonda, Director and Managing Director at Supalai, thinks the same. Supalai plans to use prefabrication for at least 50% of its overall single family homes this year and plan to expand it to 100% in 2015.

Based on the data collected from this research, the existing prefabricated products in Thailand have different strengths and weaknesses in the construction method, the length of time in construction, the process, size, price range and energy saving. Table 4.2 and 4.3 show differences and similarities between the existing prefabricated products in Thailand.

Table 4.2.Low-Rise Residential Product

Type	Construction Time for 100 sqm.	Process	Size (sqm)	Construction Cost per sqm	Energy Saving**	Building System
Concrete Panel	5 MOs+	Wet Process	100-200	$550-850	Medium	Include
Knock-Down House	3 MOs /Ready of Delivery	Dry Process*	30-100	$200-300	Low	Exclude
Steel Frame Modular	4 MOs+	Dry Process*	16-180	$600-850	Medium	Include
SCG Heim	4 MOs	Dry Process*	150-250	$800-1,000	High	Include
MYH	Ready for Delivery	Dry Process*	13.2-100	$150-200	High	Include

* Dry process except foundation

Table 4.3.Mid-Rise & High-Rise Residential Product

Type	Construction Time	Process	Size (sqm)	Construction Cost per sqm	Energy Saving**	Building System
Concrete Panel	NA	Wet + Dry Process	NA	$350-500	Medium	NA

** Energy Saving is based on the type of insulation

- Low = no insulation
- Medium = wall & roof insulation
- High = wall & roof insulation plus sealing of the whole building

From the data collected from Thai prefabricated products, we can narrow down the choices of American prefabricated products that are compatible with the Thai market. The selected products in the chapter 5 are chosen based on these criteria discussed in the next chapters.

CHAPTER 5

POTENTIAL AMERICAN PRODUCTS & METHODS

5.1 OVERVIEW

There are many prefabricated products in the U.S. that have the potential to be successful in Thailand. In the screening process, there are several criteria that are used to decide whether a product has potential for the Thai market. These criteria are based on opinions from participants from the Thai construction industry. Participants include architects, contractors, developers, construction products manufactures, and research papers (the list of participants can be found on appendix E). The criteria that are used to help select the appropriate products in this research are listed below.

- The product does not exist in Thailand
- The product can help save time in construction compared with local products
- The product has potential to replace or brace existing products or methods
- The product has easy methods that local workers can easily operate
- The product is sustainable
- The product has the potential to develop on the local market

Base on the above criteria and data that are collected from both the U.S. and Thai prefabrication, the choices of the American prefabricated products have been narrowed down to four products.

1) Structure Insulated Panels (SIPs)
2) Metal Stud Concrete Panel
3) Prefabricated Wood Wall Panel
4) Modular System

5.2 STRUCTURAL INSULATED PANELS (SIPS)

5.2.1 Description

As previously described in chapter 2, structural insulated panels (SIPs) are a high performance building system that consist of an insulating foam core sandwiched between two structural facings which are sometimes known as sandwich panels or stressed-skin panels. The panel is mainly used as a main structure of a building. It is used as a load-bearing wall for a typical residential construction. It can also be used as a floor structure, a roof structure or an interior panel. The panel is factory-built. The building process consists in injecting polyurethane foam between two siding materials in a tightly enclosed cavity (Eco-panels, 2014). The finished material (see table 5.1) that is commonly used for siding is oriented strand board (OSB) (see figure 5.1). Oriented strand board, also known as sterling board, is an engineered wood particle board. It can take high compressive strength which makes it a good choice for SIPs. The other materials are also used as sheathing depending on their strengths and weaknesses.

Table 5.1.SIPs Finish Materials Comparison

Sheathing Type	Strengths	Weaknesses
Oriented Strand Board (OSB)	Load bearing; readily available; tested; large panel size up to 8' x 24'	Subject to mold and a reduction in structural capacity if exposed to moisture; not fire resistant; must be treated for termites; difficult substrate for most common joint tapes
Sheet Metal	Resistant to mold; can be load-bearing; very light; unlimited lengths when made from coil stock	Must be galvanized or stainless steel; not load bearing
Plywood	Lateral strength	Availability; price; limited panel size; subject to mold and reduced structural capacity if exposed to moisture for a prolonged period of time; not fire resistant; must be treated for termites
Fiber Cement Siding	Resistant to mold, termites, and fire	Availability; weight; testing; limited panel size
Magnesium Board	Resistant to mold, termites, and fire	Availability; testing; limited panel size
Fiberglass Mat Gypsum Sheathing	Resistant to termites and fire	Not structural; limited panel size
Composite Structural Siding Panels	Resistant to mold and termites; pre-primed materials available	Not fire resistant

(National Institute of Building Science, 2013)

Figure 5.1: Structure insulated panel with OSB finished

(Eco-panels, 2013)

Another main component of SIPs are the form in between sheathings. There are three types of forms: expanded polystyrene (EPS), extruded polystyrene (XPS), and polyurethane foam (PUR), all of which are commonly used in filling the sheathing. As described by Simon (2013) “With EPS and XPS foam, the assembly is pressure laminated together. With PUR and PIR, the liquid foam is injected and cured under high pressure”. The strengths and weaknesses of these three types of forms can be seen in table 5.2.

Table 5.2.Foam Types Comparison

Sheathing Type	Strengths	Weaknesses
Expanded Polystyrene (EPS)	Least expensive; thickness options are only limited by the foam manufacturer; availability; fastest to modify in field; most benign blowing agent	Produced with HBCD*
Extruded Polystyrene (XPS)	Strength; water resistant	Availability; produced with HBCD*
Polyurethane Foam (PUR)	Highest R-value/inch; strength, water resistant	Most expensive; harder to modify thickness limitations; creep; availability; produced with chlorinated phosphate flame retardants**

*HBCD: hexabromocyclododecane - a brominated fire retardant classified by the European Union (REACH program) as persistent, bioaccumulative, and toxic (PBT).

(National Institute of Building Science, 2013)

5.2.2 Construction Method & Advantage

One of the biggest advantages of using SIPs is that SIPs is very easy to install. The installation method is similar to that of a wood frame construction. SIPs come to the construction site with a varity of pieces depending on the complication of the building. Two workers can easily lift the panels up and put them together without a crane, because the panels are light. The panels generally sit on the sill plate and are framed together with the head jamb. Some companies, such as Eco-Panels, have an advanced way of installation. Eco-Panels use “a quick-connect cam-lock joining solution”, a system designed to connect two panels together by using a steel lock. With the cam-lock joining solution, the panels are tightly connected and can absorb more shear load. The building that is built from SIPs can be finished in approximately 130 hrs (depending on the complexity of the design and the size). Because of the easy installation step, SIPs should gain attention when entering the Thai market. Unskilled workers can easily understand the installation process without spending a lot of time on training.

Another big advantage of using SIPs is energy saving. The in filled form has a very high R-value (Resistance Value) compared with the typical batt insulation on wood frame construction. The nominated R-value of the form varies from 3 to 6 per inch depending on the type of form. A wood frame generally has its R-value at 1 per 1 inch, and if put together with the wood frame construction wall system (with stud and insulation), its R-value can be up to R13 while SIPs has a nominated R-value at R26 (See Appendix A for energy comparison)

5.2.3 Local Market

The target market for SIPs in Thailand could be at the low to mid level house with an estimated sale price around $150,000 per unit or between $800-950 per sqm. SIPs can easily compete with most of the existing prefabricated products in Thailand. Knock-Down Houses and Steel Frame Modulars are the two products that are most similar to

SIPs' houses in terms of size, price and quality, but SIPs' houses have a big advantage over them in terms of energy saving and construction speed.

Thailand is a very hot and humid country. The average temperature in Thailand is between 30°C to 35°C (86°F to 95°F), which is very hot; the temperature can be as high as 40°C (104°F). However, most houses in Thailand do not have proper insulation. Most houses in Thailand have AC units installed, but with those very high temperatures many AC units are not capable of cooling buildings properly, or the cooling could result in a very expensive electrical bill. SIPs can defiantly help reduce AC load because it has a high R-value which can help in a long term saving.

Moreover, SIP is easy to install. Unskilled workers in Thailand can easily pick up the installation method. This can help attract more contractors and developers because the construction method is simpler than the existing brick and mortar that is widely used in Thailand. On the production side, Thailand has a lot of high standard prefabrication factories that can handle the basic need of producing SIPs. With more and more prefabrication factories built to absorb the growth of prefabrication market and the labor cost crisis, establishing a SIPs factory in Thailand should benefit both the housing market and American investors.

5.2.4 Conclusion & Problems

Due to the labor cost crisis in Thailand, prefabrication homes, such as SIP homes, could make an impact on the whole construction industry. Today, according to real estate news in Thailand, many large developers and contractors are willing to shift from brick & mortar homes to prefabricated homes. This is a great opportunity for SIPs to become one of the best choices for Thai prefabricated homes.

However, in the past, the panelized construction for single family homes in Thailand was not very successful for many reasons. First, home owners, developers and contractors were used to brick & mortar homes, which they were not ready to substitute for a new system yet. However, prefabrication is now becoming a common method in

Thailand, so now is the right time to push for it. Second, Thai people are sensitive about panelizing. They feel that panelized homes are more like temporary homes. The reason is that the finished material, such as, plywood or OSB, does not look as strong as brick or concrete. This problem can be solved from a design stand point. Finished materials, such as, fiber cement siding (which has been very popular in Thailand for the past 10 years), magnesium or gypsum board and composite structural siding panels can help achieve the aesthetic goal. The word “foam” can also be sensitive. Developers may need to avoid using this word.

A drawback for SIPs could be the impact of high humidity in Thailand. There are several reports about moisture damage and mold on SIP which could be more troublesome when using them in a tropical area. However, there are several countries in tropical areas, such as Brazil and Ghana, which currently use SIPs (Eco-panel, 2013). This requires long term research and product improvement for those special areas.

5.3 METAL STUD CONCRETE PANEL

5.3.1 Description

A metal stud concrete panel, also known as “stud cast” or “Carboncast®”, is a hybrid panel. It is a combination of a precast concrete panel and metal stud. The panel has approximately two-inch thick concrete on the exterior and standard light-gauge steel framing on the interior (see figure 5.2). It comes with a variety of finishes attached to a concrete panel. Concrete surface finish, brick and stone are good examples of this. The exterior finish is attached to the concrete panel in a very thin layer, or it is mixed with the concrete panel. This panel can be used as a load-bearing wall or as a cladding wall.

The production process is also similar to the process of other panel systems. Workers a lay set of metal studs on the flat surface, and then pour concrete on top of it, let it dry (can be as fast as 24 hours) before lifting it up and storing it. The concrete layer is connected with the metal studs by stainless steel anchor that is attached to the metal

stud. The anchor is flexible and can rotate easily, which helps reduce cracks in the thin layer of the concrete. (See Appendix B for product information)

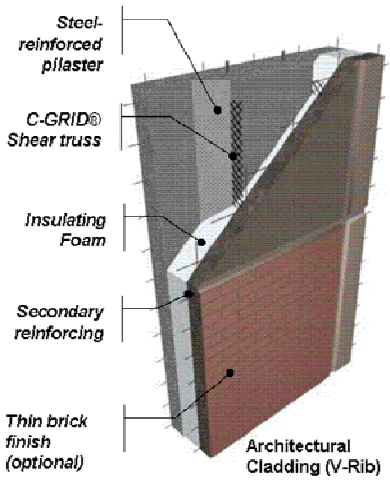


Figure 5.2: Metal stud concrete panel

(Highconcrete, 2013*)*

5.3.2 Construction Method & Advantage

The construction method is similar to the typical prefabricated light weight concrete panel. A metal stud concrete panel is a factory-built panel, so it is delivered from a factory to a construction site as a unit (some of them can be built at the construction site depending on the site's constraints). At the site, contractors need to provide a crane to help lift the panel in to the point of connection where workers can connect the panel to the floor system.

The big advantage of metal stud concrete panel is that the panel's weight is much lighter (28 lbs. per square foot) than the typical precast concrete. Owners can save up to 30% from less structure steel and less foundation, and the panel is also good with a cantilever design. The panel comes with a self-drainage system to get water out between the joints, so it can help reduce mold and moisture to the façade and the building. Insulation is also installed with the panel from a factory, so the panel meets most of the

energy codes and LEED credits. It can also reduce construction time like other precast panels by up to 50%.

5.3.3 Local Market

The metal stud concrete panel can definitely compete with the precast concrete panel in Thailand. The metal stud concrete panel not only helps save construction time, but it also requires less structure and foundation because it is lighter. Another big advantage of the metal stud concrete panel is that it has several finished materials. Currently, the precast concrete panel in Thailand can only be painted. Workers need to go outside of a building (for multi-story buildings) to paint the panel after it is installed. Many times, the painting process can slow down a construction schedule because Thailand has a rainy season of approximately 4-5 months. The rain not only slows down the construction, but sometimes, it results in a poor building surface and bad painting, which always costs long-term maintenance. Because the metal stud concrete panel comes with various finished materials that the precast concrete panel in Thailand does not have, it can give more design freedom to architects and owners.

Compared to a similar product, the prefabricated wood frame panel on drywall, the metal stud concrete panel should gain more attention in the Thai market. The prefabricated wood frame panel does not do well on the Thai market because owners and developers see wood stud as temporary material. They have the negative perception that wood structure is only for cheap construction and that dry wall, should not be used as exterior material.

5.3.4 Conclusion & Problems

One of the advantages of the metal stud concrete panel is that it can be used on all types of buildings, such as multi-family residential, commercial or factory. However, the overall construction cost is not cheap if used for a low-rise construction. It can be cheaper from the reduction of steel used and foundation in the mid to high-rise buildings. Using

the metal stud concrete panel for single family houses may not be a good idea, unless it is a prototype project which could happen in Thailand.

Another drawback is that Thai workers and contractors are not yet familiar with installing drywall and drywall details. The metal stud concrete panel has an interior side that generally needs to be finished on site. Currently, even for multifamily residential projects, most contractors still use red-brick and mortar for interior walls. There could be some struggling in the installation at the beginning, but there should not be a problem in the long term. Metal stud concrete should be a good candidate for prefabricated construction in Thailand.

5.4 PREFABRICATED WOOD PANEL

5.4.1 Description

Prefabricated wood panel or wood panelization has been in the American prefabricated industry for more than half a century. It is the most common prefabricated construction type in the U.S. and is known by to most American contractors. The panels are simply made from a set of wood studs which is similar to the stick-built construction method. A set of wood studs is laid down horizontally in the factory before workers connect them together by nails and lumber similar to stick framing. The openings are provided according to the design, but most window units are assembled onsite. After the framing is assembled, the exterior sheets (can be plywood or OSB) are attached to the prefabricated framing while interior wall panels can often be seen as open frames. The exterior panels can come with a variety of finishes, such as, stucco finish, siding or brick veneer and it can be done either on a construction site or from a factory.

The panels can be either a load-bearing panel or a non-load-bearing panel. They are often used for both single-family construction and mid-rise multifamily construction (generally two- to four-story). The prefabricated wood panels can also be used as floor and roof units.

5.4.2 Construction Method & Advantage

The construction method for prefabricated wood panels is very simple. The prefabricated wood panels are delivered to a construction site before being assembled. Prefabricated wood panel can easily attached to both wood floor structures and concrete floor structures depend on the detail and construction type.

The advantage of using prefabricated wood panel is that wood panel is cost-effective compare to gauge steel panels. Prefabricated wood panel is a light weight material which can help owner save more upfront cost from using lighter structure and smaller foundation. Moreover, wood is a renewable material. It is environmental friendly and life cycle assessment studies consistently show that wood offers environmental advantages in terms of embodied energy, air and water pollution, and other impact indicators (Architectural Record, 2014).

5.4.3 Local Market

The strength of prefabricated wood panel is that it is cheaper than other types of prefabrication. In Thai suburb and country side, a three- to five-story brick building is a standard type of affordable apartment home. This type of building generally uses the most common type of construction, red-brick & mortar, and uses the cheapest and lowest quality of finish, paint on masonry wall. Red brick & mortar is the most common type of construction in Thailand; however, it can cause a lot of problems if contractors do not understand the whole process or do not carefully build. For example, using wrong type of concrete, mortar or paint, or rush to pour concrete will result in crack, peel or collapse. There are many cases that Thai contractors, especially in the suburb area, build a low quality building which many times result in lawsuit. Prefabricated wood panel can be a good candidate for this type of building in Thailand because the affordable apartment is considered a small size multifamily. The building is generally built not taller than five-story height which suits with prefabricated wood panel.

5.4.4 Conclusion & Problems

Prefabricated wood panel has a potential to be successful in Thailand but it may be suited only for few types of building (affordable apartment). The affordable apartment in Thailand is normally a three- to five-story height which is a normal height for a prefabricated wood panel building. Unlike condominiums, affordable apartments in Thailand are built from the cheapest available method. The low-income tenants do not care much on how the building is built. On the other hand, condo buyers are fastidious buyers. Many of them have a red flag on wood frame construction for mid-rise building (more than three-story). Their perception for wood frame construction is that wood frame construction might not last long and is not strong enough to survive natural disaster.

Prefabricated wood panel and wood frame construction are considered as cheaper choices for mid-rise building in the U.S.; however, the cost of using wood construction in Thailand is not much difference compare to cost of typical red brick & mortar construction. Moreover, wood is considered a precious material in Thailand. The common wood species, which are commonly used in construction, for example, teak (Mai Sak), and iron wood (Mai Dang) are very expensive. The cheaper species, for example, keruing wood (Mai Yarng), and pine wood, are available for a cheaper cost but the quality of those wood are not as good as the quality in the United States. The major problem of wood construction in Thailand is that the qualities of woods are low. Many times, the low quality woods, which are used in a cheap type construction, are not completely dry which result in a long term damage to a building. The better quality wood is expensive and not often used for large constructions. This could be a major drawback for prefabricated wood panels in Thailand.

5.5 MULTIFAMILY MODULAR

5.5.1 Description

The modular system has been a common method in the U.S construction for years. The technology has been developed from a small scale modular like a single

family home modular to a large scale modular like the 32 story-apartment in Brooklyn, New York. In general, modular building is the same type of traditional construction building. A modular building is built in the same way as other on site construction buildings; the same material, structure, and code are used in both types of buildings. The only difference is that modular building is built in a controlled environment.

5.5.2 Construction Method & Advantage

The installation process in the modular system is very simple. For low-rise and mid-rise buildings (generally, between 2-5 stories), the construction process is very easy. The modular units are transported to a construction site by a large truck and lifted up to the place by a crane; then workers stack them on top of each other, seal and finish (see figure 5.3). This easy process can help save time for construction from 30-50% (Modular Building Institute, 2013). The modular system also offers a safer construction site environment and reduces waste from the construction site, so the process can be considered as “lean construction”.

Figure 5.3: Modular construction for multifamily residential (http:// www.modularhomeassociation.org, 2013*)*

For high-rise buildings, the process can be slower because the phase of installing the modular system depends on the phase of constructing the main structure. However, after the main structure is built the installation process can be very fast. The limitation could be that most high-rise buildings are located inside the city area, which can make it difficult to use a large truck.

5.5.3 Local Market

There are only 3-4 manufacturers in Thailand that produce modular products, and all of them focus only at a small scale. Today, the market of the multifamily modular in Thailand is very small, but it has the potential to grow very fast in the near future. Building types such as low-rise and mid-rise apartments or private dormitories could be good targets. These types of buildings can be very compatible with the modular system because they need the shortest schedule as possible, and most of them are located outside busy business areas where large trucks can be used.

Currently, these types of buildings are built using the red-brick and mortar methods. The average construction time for a three-story building with approximately 30-40 units can take about one year to build. Another problem is that many contractors who do tow or mid rise buildings are small size companies which often do not build buildings that meet the standards. Modular construction could have a big impact on these types of building because it offers higher standards, factory-built buildings; this reduces the risk of low quality building to owners.

5.5.4 Conclusion & Problems

Multifamily modular should do well in Thailand. The country has the ability to produce such high quality building materials, so producing multifamily modular units should be fine. At the beginning, the product may be appropriate only for a rental market because renters have less concern about how buildings are built, while buyers are concerned more about the structure; they are more likely to choose buildings that are made from red-bricks or concrete panels than by the metal stud modular unit. However,

in the long run, people should get used to this type of construction and with advanced products and competitive prices, multifamily modular building should be able to compete nationally.

The drawback is not only that multifamily modular has not yet gained buyers' trust but that it also has some limitations when it is transported. Most of the roads and high ways in Thailand are smaller than those in the United States. Moreover, the truck size in Thailand is a lot smaller than the truck size in the United States. Transporting modular units to a construction site could be challenging. As a result, the typical module of multifamily units (room dimension) in Thailand is smaller than the module in the United States. This requires a more detailed study for the appropriate dimension that would work with both the unit and the transportation, but since there are several modular homes that are currently sold on the Thai market; this may not be an issue.

5.6 PRODUCT COMPARISON

After collecting data from the four selected products, we can now compare those four selected products with the existing local products. First, the four selected products can do as well as the current local Thai prefabricated products, or even better. The easy installation process should gain a lot attention from developers and contractors. One of the biggest advantages of the four selected products is that all four products can produce high energy saving building. Most Thai prefabricated products produce none or low energy saving buildings, so this could be the big advantage for the U.S. products over the local products.

The drawback for the U.S. products for the international market could be the price. Currently, the prices of these four selected products are higher compared with the prices of local competitors. However, the labor cost in Thailand is significantly lower compared with the American labor cost. The lowest minimum wage in the U.S. is $7.25 per hour (Department of labor), while the minimum wage in Thailand is $9.00 per day (8-

10 hours). This lower wage in Thailand could help reduce the upfront cost for American prefabrication if the factory is established in Thailand.

Table 5.3 and table 5.4 show the comparison between the existing Thai prefabricated products and the selected American prefabricated products.

Table 5.3.Low-Rise Residential Products

Existing Products						
Type	Construction Time for 100 sqm.	Process	Size (sqm)	Construction Cost per sqm	Energy Saving	Building System
Concrete Panel	5 MOs+	Wet Process	100-200	$550-850	Medium	Include
Knock-Down House	3 MOs /Ready of Delivery	Dry Process	30-100	$200-300	Low	Exclude
Steel Frame Modular	4 MOs+	Dry Process	16-180	$600-850	Medium	Include
SCG Heim	4 MOs	Dry Process	150-250	$800-1,000	High	Include
MYH	Ready for Delivery	Dry Process	13.2-100	$150-200	High	Include
Selected Products						
SIPs	1 MOs+	Dry Process	100-300	700-800***	High	Include
Prefabricated Wood Panel	1 MOs+	Dry Process	100-300	400-500***	High	Include
Metal Stud Concrete	1 MOs+	Dry Process	100-300	800-900***	High	Include
Modular	Less than 1 MOs	Dry Process	100-300	800-1,000***	High	Include

Table 5.4.Mid-Rise & High-Rise Residential

Type	Construction Time	Process	Size (sqm)	Construction Cost per sqm	Energy Saving**	Building System
Concrete Panel	NA	Wet + Dry Process	NA	350-500	Medium	NA
Selected Products						
Prefabricated Wood Panel	NA	Dry Process	NA	250-300***	High	Include
Metal Stud Concrete	NA	Dry Process	NA	550-800***	High	Include
Modular	NA	Dry Process	NA	500-650***	High	Include

*** Construction cost in the U.S.

According to the tables (tables 5.3 & 5.4), the four selected products can save construction time significantly. This also means saving money for a lot of owners from construction loans, and construction costs; and the project can open sooner.

In the single family home sector, SIPs can easily compete with knock-down houses and steel frames, but it may be very difficult to compete with SCG Heim because SCG Heim is built in such a higher quality and with better equipment. The precast concrete panel for single family, mid-rise and high-rise sector can be replaced by metal stud concrete or prefabricated wood panels (for mid-rise construction), which offers less weight and faster construction time. Moreover, instead of painting a precast concrete panel on site, metal stud concrete and prefabricated wood panels offer a variety of finishes that give more options to architects and owners. Workers do not need to do anymore work to the exterior panels after the panels are installed.

Multifamily modular units can have real challenge in the current Thai market. Since there is no similar product for this type of product yet, opening a new market for multifamily modular will require a lot of efforts. However, for the reasons provided in previous chapters, this product can become very popular in the near future.

Tables 5.5 shows the selection criteria, from page 58, and four selected products compared with the existing prefabricated products in a scoring system.

Table 5.5: Selected products' scores compared to local products

	Does not exist in Thailand	Saves time compared with local method	Potential to compete with local products	Competitive Price	Easy to assemble	Sustainable
SIPs	xxx	xx	xx	x	xxx	xxx
Metal Stud Concrete Panel	xx	xx	xxx	x	x	xxx
Prefabricated Wood Panel	xx	xx	xx	x	x	xxx
Modular System	xxx	xxx	xx	x	xx	xxx

According to table 5.5, the table shows the strength of the four selected products compared with the existing local products. The scoring system, X = worse or equal, XX = better, XXX = excellent, is based on the comparison to Thai products. The list below explains the scoring system criteria in categories.

“Does not exist in Thailand”: The four selected products are new in Thailand. However, metal stud concrete panels and prefabricated wood panels are similar products to the concrete panels, so they all get minus X from full XXX credits. SIPs and modular systems have never been used in Thailand, so these two get full XXX credits.

“Saves time compared with local method”: As previously shown in table 5.3, the four selected products have shorter construction time compared to the four existing prefabricated products (on MYH home is faster because it is pre-made and ready to deliver). SIPs, metal stud concrete panels and prefabricated wood panels get XX for faster construction time, while the modular system gets XXX because its construction time is the fastest.

“Potential to compete with local products”: All four selected products are definitely able to compete with those existing prefabricated in Thailand. However, SIPs, prefabricated wood panels and modular systems have never been tested in the market. There are some risks associated with bringing in the new products, so they all get minus X from full XXX credits. On the other hands, metal stud concrete panels are similar products with the concrete panel system in Thailand, but they are better in quality, have various finishes, and are more sustainable than local concrete panels, so they earned XXX credits.

“Competitive Price”: According to table 5.3, the four selected products are expensive products compared with local prefabricated products, so all products get one X credit. However, the prices are based on the U.S. market, so they could reduce when the products are sold in the Thai market.

“Easy to assemble”: Although the construction time for the four selected products are faster than the local prefabricated products, the assembly processes are different. Metal stud concrete panels and prefabricated wood panels are similar products with concrete panels, so the assemblies processes are no difference than the concrete panels’ process which make them earn only one X credit. The modular systems’ assemble process is simple, but it require some large machines for assembly, so it gets minus one X credit. SIPs’ assembly process is the easiest process compared with local prefabrication’s processes and other selected products. Workers can easily pick the panels up and install them to the site because they are light.

“Sustainable”: All four selected products have high efficiency energy saving rates which are greater than those of all the local products. This is one of the key strength the selected products have when competing with the local products.

In conclusion, all four selected products received scores between 11 to 14 credits.

- SIPs = 14 credits
- Metal stud concrete panels = 12 credits
- Prefabricated wood panels = 11 credits
- Modular system = 14 credits

The category in which the selected products received the least credits is “competitive price”. Therefore, the price could be the key improvement for those four selected products for the Thai market. On the other hands, the category in which they received the most score is “sustainable”, so sustainability could be the big selling point for all those selected products in the Thai market.

CHAPTER 6

CONCLUSIONS

6.1 OPINIONS

After interviewing construction specialists and manufacturers from both Thais and Americans, it was clear that they all had different opinions on the U.S. prefabrication in Thailand.

6.1.1 Thai Specialists

Thai participants in this research were architects, owners, developers, and manufacturers. Thai architects think that, sooner or later, prefabrication will play a big role in Thai construction. The world is more connected now than ever before, so the new products or methods from Western countries will come and compete or join with local manufacturers. As architects, they need to improve their knowledge to be able to work with any type of construction that is available on the market.

Second, Thai developers think prefabrication can help them save more cost from both labor and schedule. However, they are not willing to try the whole new project with one type of construction. The coming project will be a hybrid between the traditional construction method with partial prefabrication. Thai contractors think preconstruction can help them on faster schedule and reduce risk from a construction site. They feel that they have a limited knowledge of prefabrication, but many of them are willing to try. Lastly, Thai manufacturers and distributors feel that they are capable of producing the selected products. They feel that those three products have potential in the Thai market if they can compete in price. The list of participants can be found in appendix E.

6.1.2 American Manufacturers

On the U.S. side, the groups of participants came from the manufacturers of the selected products, SIPs, metal stud concrete panels, prefabricated wood panels and the modular system. First, the SIPs “manufacturers think their product has a big advantage in a hot climate area like Thailand. In order to be competitive with local products, the factory needs to be in Thailand to cut transportation costs. However, SIPs manufacturers worry about the volume and marketing. They doubt that the product can get enough market shares to offset factory costs. Moreover, they worry about the copy right in Thailand.

Second, the concrete panel manufacturers think that they should be able to compete with the similar type of product. Just like SIPs manufacturers, they also worry about the volume, marketing, and local suppliers. They feel that the product needs to be developed more to suit with the local standards. Next, wood panel manufacturers have an interest in sending their product overseas, however, because of the location they feel somewhat disadvantaged over similar companies located closer to the major shipping points in the U.S. As far as pricing goes wood wall panel business is volatile due to base pricing on lumber which fluctuates greatly from week to week. The wood frame can also be substituted for metal frame, if wood is not available or if it is difficult to access it overseas.

Finally, the modular manufacturers think that if they can expand their product to more countries, it would be great. Currently, they have tried to expand their market to Asian countries, such as India, so they think that expanding to Thailand could be a good opportunity. Some companies have already established their offices in India. However, they worry about the sale volume because Thailand doesn’t have as many people as India. The list of participants can be found in appendix E.

6.2 RECOMMENDATIONS

6.2.1 Recommendations for owners

Prefabrication gives a lot of benefits to projects. It can help save times and money for most projects. There are several prefabricated products that are currently available in Thailand and many U.S. prefabricated products that have high potentials to be used in Thailand. Owners need to make sure they clearly understand the products before selecting the process. Some products can be useful only if used as a whole system, some of them can be used with other construction methods.

Most products that are imported from must be developed to suit with the local geography and climate before using. Untested products may be significantly costly to projects. Moreover, some products suit only with some types of projects. Using inappropriate products may result in more cost or future problems.

6.2.2 Recommendations for contractors

A prefabricated product is designed to be an easy installation product. However, contractors and workers must make sure they understand all the processes and construction drawings before starting a project. There were many cases where Thai contractors did not follow instructions properly, and which resulted in loss both in time and money. Following instructions properly can also help reduce risk at construction site.

Preciseness is also a critical thing when using prefabrication. Deflection in construction may result in a delay and failure of a prefabrication system. Transportation and storage can also be critical issues with prefabricated construction.

6.2.3 Recommendations for distributors and manufacturers

Prefabricated products and methods are not new in Thailand. However, many people who are not involved in a construction business still don’t know the difference between the traditional constructions and prefabrications. Distributors must provide all the necessary information to buyers, so they don’t misunderstand the concept and method of prefabrication.

Preciseness from a factory side is also as important as preciseness from a construction side. Low-standard products can cause significant loss to projects. Unlike in traditional construction with prefabrication, workers do not need to adjust prefabricated products much at a construction site. Good products from good manufacturers will shorten construction time as much as 50% from a traditional construction method.

6.3 CONCLUSIONS

American prefabrication should do well in many developing Asian countries, including Thailand. The key to success for American prefabricated products in Thailand is that most of them have strengths over most of the existing Thai prefabricated products in the market. Energy saving and easy assembly are two main key which make American prefabricated products interesting and competitive with the local products. However, there are other factors which American investors must understand before investing in developing Asia countries. Good products or high quality products are not always the most desired products. American prefabricated products absolutely have better standards than many local prefabricated products. However, not all the high standards are required or attract local buyers. Moreover, products which are really compatible with the American environment may not always compatible with Asian environment. American manufacturers need to develop their products to suit with the local climate, geography as well as local desires.

In addition, the sale price in the U.S. won’t make the products sell well in Thailand. American manufacturers need to establish their plants locally or join with large local distributors and manufacturers, in order to be competitive with the price; this can also help protect their copyrights. The four selected products have high potential to be very successful in Thailand because they do not need much upfront costs that special machine may cause, for example. Those products can easily be produced from local factories which can help reduce the risk of putting a lot of high upfront cost.

Currently, real estate in Thailand is booming; it has been booming for the past three years. This year, the overall sale has slowed down a bit due to the unstability of the government. However, the launching of the ASEAN Economic Community in 2015 should attract many investors. Because Thailand is the center of business for many South East Asian countries around, such as, Malaysia, Myanmar, Laos, Vietnam and Cambodia, investing or establishing plants in Thailand has an advantage of distributing the products to many countries. Thailand is a great place to invest, and investing in Thailand will benefit both American companies and Thai people.

APPENDIX A

CASE STUDY I

Case Study: Habitia Watcharapol

Location: Saimai, Bangkok, Thailand

Company: Sansiri

Sansiri, one of the largest residential developing companies in Thailand, has produced the mid-size prefabricated homes on the market by using the close system prefabricated concrete method. In 2011, Sansiri produced more than 8,000 residential units which approximately 4,800 units are mid-size homes. More than 50% of its mid-size homes used the close system while the larger units are still being built as skeleton method. Although Sansiri's homes are not fully prefabricated buildings, 70% of the construction material is prefabrication. The construction process can be divided in to five steps as described below.

Step One: Foundation: Contractor uses the same method as the foundation for skeleton structure. The methods consist in hammering the concreted piles and pouring the foundation. These foundations have steel plates that, later, will be used to connect the first floor beams (see figure A.1 & A.2). This method cannot use the prefabricated foundation because of the variation of the site and soil, so it is the slowest process.

Figure A.1: Cast in Place Foundation

(Author's photo, 2013)

Figure A.2: Steel Plate, embedded to the foundation

(Author's photo, 2013)

Step Two: First Floor Beam: After pouring the concrete foundation and letting the concrete set, workers install prefabricated beams (see figure A.3 & A.4). The concrete beams are casted from a factory before being transportd to the site construction. The beams will be connected to the foundation by welding the steel plates together before pouring concrete on top of the connector.

Figure A.3: Cast in Place Foundation with Precast Concrete Beam

(Author's photo, 2013)

Figure A.4: Precast Concrete Beam

(Author's photo, 2013)

Step Three: Floor and Wall: After the first floor beams are installed, worker will install floor concrete slabs and wall panels (see figure A.5). Floors and walls are prefabricated concrete which are delivered from the factory. Worker will work with small cranes to lift up walls and floors to the place where they can weld them together. After installing prefabricated walls, workers need to close the gap between two walls by using mortar cement (see figure A.6). The stair is also a prefabricated concrete stair that can be installed by a small crane.

Figure A.5: Precast Wall Panel, after installed

(Author's photo, 2013)

Figure A.6: Mortar Cement Joint

(Author's photo, 2013)

Step Four: Roofing: Roofing structures are made from prefabricated steel, but those steels require onsite installation (see figure A.7). Although those steel require onsite installation, the process is a lot faster than the old concrete method. The installation of the prefabricated steel is a dry process. Workers only need to connect the steels by bolt, so there is no waiting time like these is in the concrete roof structure process. After finishing the roof frame, workers will install the roof tiles (see figure A.8). This process can take a little longer than the framing process.

Figure A.7: Roof Framing

(Author's photo, 2013)

Figure A.8: Roof, after roof tiles are installed

(Author's photo, 2013)

Step Five: Finishing: This is the last process of Sansiri's prefabricated homes. This process also takes the majority of the time in the onsite construction. Typically, Sansiri's prefabricated homes take from 4 to 6 months to build, but the finishing process may take up to 2 to 3 months depending on the size of the homes. This process includes the installation of windows and doors (windows are also prefabricated units that are delivered from a sub-contractor's factory), the painting of the exterior and interior, the installation of the floor finishing and sanitary units (see figure A.9).

Figure A.9: Finished Product

(Author's photo, 2013)

Comment: This year, Sansiri opened a new 42-acre precast factory in the suburb of Bangkok to increase the volume of their prefabricated homes. The technology and machines are imported from Germany. Currently, the 2013 Sansiri's prefabricated home is still not fully prefabrication, yet it is a good start. With the new technology, Sansiri believes that it can solve the problems of the concrete panel and expand the product line. The problems of the panel are such as the preciseness and the quality. More than fifty percent of the panels that were delivered to the construction site need to be carved to remove the surplus concrete out from their surface. This problem occurs because of the low quality of the mold. Spots are frequently seen the surplus in the opening areas such as doors and windows. This carving process requires a lot of manpower and time which may delay the installation process. Transportation and onsite management have also become a factor for Sansiri's homes. Both methods cost the loss of the concrete panels for more than 15% for each project. Good constructions management and good logistics will help reduce this loss.

APPENDIX B

CASE STUDY II

Case Study: LPN Bang Na

Location: Bang Na, Bangkok, Thailand

Company: LPN

LPN (Lumpini) has been in the market of affordable condominium for more than ten years. The concepts of the affordable are such as small units, less expensive material which can reduce the construction cost. However, the prefabricated concrete panel system costs more than the typical masonry wall (it is as much as 200% more expensive than masonry wall), but it helps save time during a construction which gives more benefit to the overall project in term of cost. The installation process is not complicated many contractors can adapt to it and use it easily. The processes can be defined as follows:

Step One: Lift the panel: The panel, which is delivered to the construction site, will be lifted by a large crane to the spot where workers can hold it (see figure B.1).

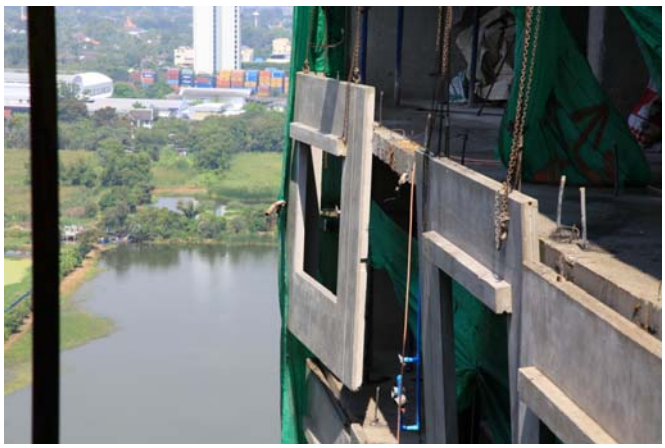


Figure B.1: Precast Panel is being lifted

(Author's photo, 2013)

Step Two: Install the panel: After the panel is in place, workers connect the panel with the main structure by welding the steel plate together (see figure B.2).

Figure B.2: Worker is welding the steel plates together.

(Author's photo, 2013)

Step Three: Sealing: Workers put sealant and backer rod in between the panels before sealing them together (see figure B.3).

Figure B.3: Sealant Joint

(Author's photo, 2013)

Step Four: Finishing: The last process is cleaning and painting (see figure B.4).

Figure B.4: Precast Panel, after painted

(Author's photo, 2013)

Comment: The prefabricated concrete panel for multifamily home is only the beginning of prefabrication in high-rise construction. The other components of the building are not prefabrication, for example, floors, columns and beams are cast in place concrete. These building components have potential to be made as prefabrication. Currently, contractor claims that using cast in place concrete floors, columns and beams are faster than prefabricated floors and columns and beams by 15-20% of the construction time for each floor. This happens because most of contractors in Thailand still do not have enough knowledge of prefabrication in a high-rise building. However, Thai developers see the potential of using more prefabrication for this type of building, so the next generation of affordable condominium in Thailand can be seen in more prefabrication.

APPENDIX C

STRUCTURE INSULATED PANELS (SIPS): ENERGY EFICIENTCY RATING

WHY SIPS?

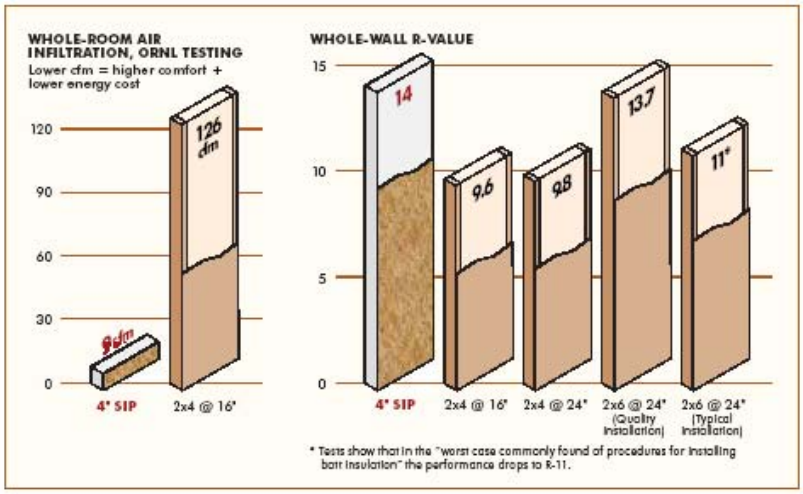
SIPs are a building system that can save builders time, money and labor while producing high-performance, green buildings.

SIPs Save Energy

Energy use and thermal efficiency are two of the anchor points of a green building. Buildings that use less energy and generate less carbon dioxide emissions have a smaller impact on the environment.

The insulating core of a structural insulated panel provides high-density continuous insulation. SIPs enable structures to be assembled with minimal framing. The percentage of area in a wall assembly composed of sawn lumber is classified as a wall's "framing factor." The framing factor is a measure of thermal bridging. The more framing, the higher the framing factor and the more energy is lost due to thermal bridging. A typical stick-framed home averages a framing factor ranging from 15 to 25 percent, while a SIP home averages a framing factor of only 3 percent. When the whole-wall R-value is measured, SIP walls outperform stick-framed walls because studs placed 16 or 24 inches on center cause thermal bridging and result in energy loss. Additionally, fiberglass and other insulating materials are subject to gaps, voids, or compression leading to further degradation in thermal performance.

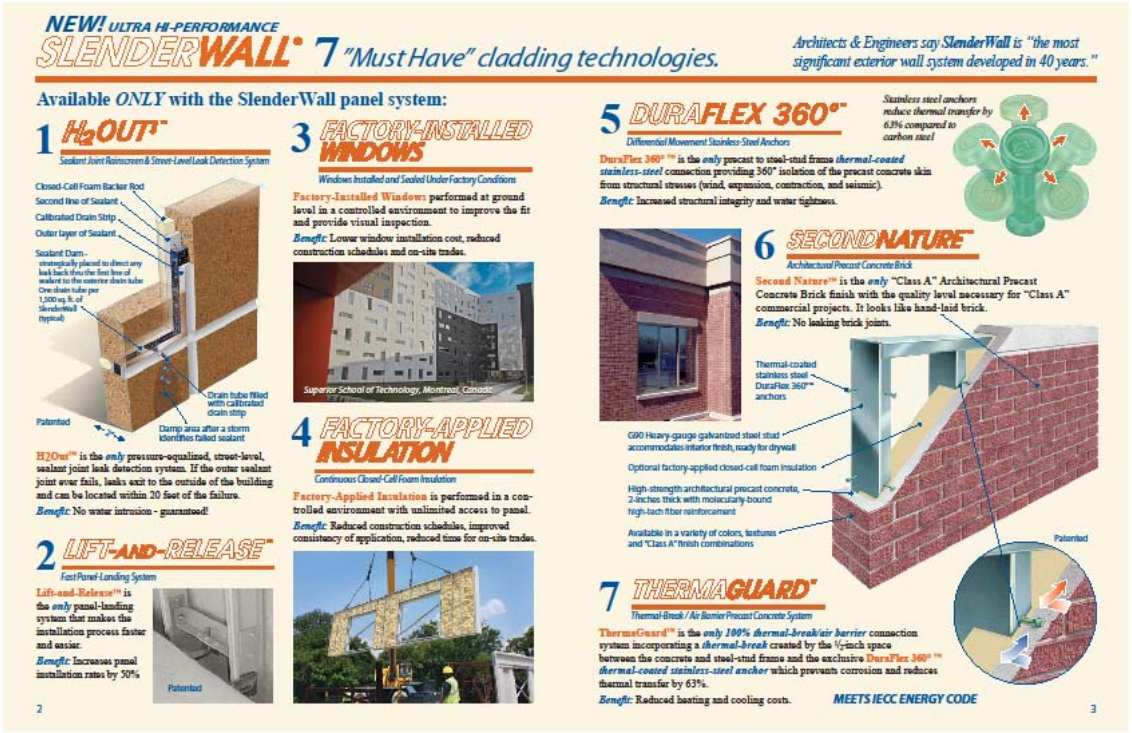
When working with panels as large as 8'x24' there are significantly fewer joints that require sealing. SIPs make establishing a whole house air barrier simple and effective. Studies at the U.S. Department of Energy's (DOE) Oak Ridge National Laboratory (ORNL) have shown a SIP room to have 90 percent less leakage than its stick-framed counterpart.[1]



(1) Christian, Jeff and T.W. Petrie, Hearing and Blower Door Tests of the Rooms for the SIPA/Reiker Project. ORNL March 15, 2002.

APPENDIX D

METAL STUD CONCRETE PANEL: SLENDERWALL



APPENDIX E

LIST OF PARTICIPANTS

Thai experts

- Trisingi Studio Co.,Ltd. (Architect)
- MekaDSGN (Architect)
- L.P.N. Development Public Co., Ltd. (Developer/Contractor)
- Sansiri PCL (Developer/Contractor)
- Pruksa Real Estate (Developer/Contractor)
- Mice Management Co.,Ltd (Contractor)
- SCG Experience (Manufacture)

American manufactures

- Eco-Panel
- Georgia Panel
- Slenderwall
- Edgewood Company
- Modular Institute

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